STUDIES ON THE ECOLOGY OF AQUATIC INSECTS WITH SPECIAL REFERENCE TO FISHPONDS

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I certify that the thesis entitled "STUDIES ON THE ECOLOGY OF AQUATIC INSECTS WITH SPECIAL REFERENCE TO FISHPONDS", submitted by Mr. A.K. Ziauddin Ahmed, for the Degree of Doctor of Philosophy of the Northeastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree.

This work has not been submitted for any degree of any other University.

R George Michael
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Insects are the dominant group of animals on earth to-day. There are very few places in the world which insects have not adopted as a place to live. The freshwaters of the earth - rivers, streams, lakes and ponds, harbour a great variety of insects from many different groups and orders. Some live there throughout their life but others spend only their larval or nymphal phases (stages) in the water. Although less than four per cent of the total number of insect species occur in or on water at some time during their life histories (Pennak, 1953), aquatic insects are important components of any freshwater ecosystem. A study of these insects in a given area provides insight into their basic ecology and their zoogeographic affinities.

Two basic facets of any freshwater ecosystem are the material cycling and energy flow. A significant portion of such cycling and flow involves the processing of various forms of organic matter by freshwater invertebrates - especially the insects. This constitutes a basis for the increasing interest in aquatic insect studies, in recent years.

Aquatic insects may also serve as indicators of the degree and severity of organic pollution. Since aquatic insects are bound to an aquatic habitat for most of the period in their life-cycles, even the changes in population, species composition and numbers may indicate a change in water quality. Recent studies (Gaufin, 1973) have shown that environmental stress may have an impact on species diversity, especially on some insect groups. Insect species have very narrow tolerance ranges, in relation to temperature, turbidity and oxygen content. Thus by studying them, it is possible to anticipate the impact of pollution even before drastic chemical and physical changes have occurred (Baumann, 1977). It is for the above reasons that the aquatic insects have gained importance and are usually included in environmental assessments and impact statements.

Aquatic insects constitute an important source of food for both the culturable and game fishes (Prejs, 1973; Cadwallder, 1975 and Guziur, 1976). Immature stages of most aquatic insects are of outstanding importance in the foodchains of freshwaters leading to fish production. This is largely due to the great extent they convert plant material into animal tissues that is utilizable by carnivorous food and game fishes (Lagler, 1952). However, aquatic stages of some insect groups have evolved predatory propensities upon small fish. Their adverse influence on fish culture, particularly in the nurseries and rearing ponds has been recognised by a number of earlier workers (Hungerford, 1919; Champlain, 1954; Khan and Hussain, 1947; Pakrasi, 1954; Alikunhi et al, 1955; Berezina, 1960; Ganguli and Mitra, 1961). In addition to causing direct mortality, these insects actively compete with spawn and fry for food to the detriment of the latter. Thus, an adequate understanding of the ecology of these insects is an essential prerequisite for successful fish culture operations and sound management strategy in aquaculture practices.

The hilly region of North-East India, with its unique topographical and climatic conditions, have large numbers of freshwater ponds, pools, lakes, streams and rivers. These varied water bodies have great potential for projects on fishery development. Unfortunately, except for a few recent studies (Gupta and Michael, 1979 and Gupta, 1980), practically no sound scientific information is available on the ecology of aquatic insects of these water bodies. In view of this paucity of information, the present investigations were undertaken to study the ecology of aquatic insects of lentic water bodies with special reference to fishponds. The investigations were carried out with the following objectives :

i) To study the seasonality of occurrence of aquatic insects in four fishponds, their relative abundance (numbers) and standing crop (biomass). To study the influence of physico-chemical factors on the insect population.

ii) To study the migration and dispersal of aquatic insects belonging to the orders Hemiptera and Coleoptera, by the use of light-traps.

iii) To assess the population size and rate of colonization by using artificial substrates imitating natural vegetation.

iv) To understand the predatory propensities of a dragonfly nymph which is common in nursery ponds.

v) To establish the species composition of aquatic insects in twenty lentic water bodies, their relative abundance and seasonality of occurrence.

Ecology of freshwater insects had attracted the attention of workers from different parts of the world for a long time with the result that over the years, a large body of knowledge had been accumulated.

Sharp (1882), Calvert (1893), Needham and Betten (1901), Miall (1903), Bueno (1906), Holmes (1907), Boving (1910, 1914), Sherman (1913) and Blunck (1914) were among the pioneering workers of freshwater insects. Edward (1915) was the first to look into the ecology of blackflies in Britain. Useful information on the life history and ecology of odonates of Washington, Oregon, Central California and Nevada in the United States of America was also recorded in subsequent years (Kennedy, 1915, 1917). A qualitative and quantitative survey of the fauna of Lake Mendota, with special reference to insects was made by Muttkowski (1918). Around this period, the biology of dragonflies and the biology and ecology of aquatic and semiaquatic Hemiptera were documented by Tillyard (1917) and Hungerford (1919) respectively. Poisson (1921, 1924) also contributed to the study of aquatic Hemiptera. The life history of water beetles and its relation to pond fish culture was focussed (Wilson, 1923). Subsequently, works on the biology of mayflies was reviewed by Needham et al (1935), while Corbet (1962) reviewed works on the ecology and behaviour of dragonflies. Studies on various aspects of the ecology of aquatic insects was also reviewed by Macan (1962a), which included most of the European works. In another publication, Cummins (1973) reviewed the works on the trophic relations of aquatic insects. Recently, Corbet (1980) in a supplement to his earlier publication, further reviewed the main features of dragonfly life history.

The habit, habitat, colonization and distribution of aquatic insects have been studied by many workers. The evolution of aquatic habitats with special reference to the distribution of Corixidae was analysed (Macan, 1938). It was found that particular corixid species complexes that have evolved were indicative of habitat types in Britain (Macan, 1954). Further, Macan (1962) threw light as to why some pieces of water hold more corixidae than others. It was also revealed that the succession of species of corixidae in english meres is very like that of Denmark (Macan, 1967). In a study on the type locality and habitat of *Hydroporus dixianus* (Coleoptera: Dytiscidae), Young (1955) recorded several minor habitats along the margin of a stream, each with a distinctive assemblage of aquatic beetles. In another study of water beetles of a temporary pond, Young (1960) concluded that the greater part of the list of species of any particular pond, is largely composed of species which migrate in from habitats in the surrounding area, and are characteristic of other habitats in the region. It was shown that differences in life history, adaptation to withstand drying, mobility at various times of their life cycles and type of habitat suitable for hibernation are some of the factors affecting the pattern of colonization of any particular species of Coleoptera (Fernando, 1958). Studies on the problem of habitat selection by flying aquatic insects indicated that a high proportion of the randomly arriving insects leave soon afterwards and in the case of Hemiptera selections seems to occur before reaching the habitat (Fernando and Galbraith, 1973). It was pointed out that most species of aquatic insects are each restricted to a narrow range of at least some ecological conditions and that many aquatic communities include far fewer species than do most terrestrial communities (Ross, 1967). The ecology of Malaysian odonates with particular reference to adult and larval biotopes and their interrelationships was also studied (Furtado, 1969). It was argued that for many odonate species biotope-restriction and biotope-preference involve not only the biotic and abiotic factors of the environment (egg, larvae) but also psychological factors within the adult individual (Jacob, 1969). That Odonata may serve as indicators of type of habitat was suggested in a study in Quebec (Fernet and Pilon, 1970). It was revealed that lime containing small ponds offer the most favourable living conditions to the Haliplidae beetles (Seeger, 1971). Small lakes and spring with stable hydrobiological conditions has been suggested to be very suitable sites for hibernation of water beetles (Lundberg and Muller, 1977). Gittelman and Severance (1975) in their studies on habitat preference of two Notonectidae (Hemiptera) showed that Buenoa confusa occurs in larger, more stable ponds than Buenoa margaritacea. Pajunen and Jansson (1969) observed that corixid population inhabiting small rock pools were highly dispersive and dispersal was intense enough to enable corixids to exploit the ephemerality and discontinuity of the habitat. Co-existence of two competing corixid species in an archipelago of rock pools appears to be facilitated by the division of the environment based on time axis (Vepsalainen, 1978). The seasonal distribution of Gerris species caught in glass trap, was found to be due to differences in habitat selection before and after overwintering (Landin and Vepsalainen, 1977). Studies on the ecology of Chironomidae in a polar lake showed that while some species are characteristic of the sediment zone, others are restricted mainly to the rocky and moss zones (Welch, 1976). Kittle (1977) while studying the biology of water striders (Hemiptera: Gerridae) in Northwest Arkansas, observed that although seven species were restricted primarily to streams, five species were commonly collected from both lentic and lotic habitats.

Population studies on aquatic insects has received considerable attention in the past few decades. In a study on the adult population of Pyrrhosoma nymphula, Corbet (1952) reported that time and synchronization of emergence is effected by the larval life history. In subsequent studies, Corbet (1954, 1962) divided British Odonata into two ecological categories, "Spring species" and "Summer species" based on the role of diapause and the timing and synchrony of emergence. It was concluded that a fundamental difference between 'spring' and 'summer' species is that the former achieve synchronization when temperature are falling, but the latter when they are rising (Corbet, 1958). Comparative studies of the temporal pattern of emergence of aquatic insects revealed four basic patterns: (i) continuous with irregular fluctuations in rate, (ii) rhythmic with a lunar period, (iii) sporadic, occurring at irregular intervals of a few days and (iv) seasonal (Corbet, 1964). In high Arctic Chironomidae (Diptera), the time of emergence in a given pond is primarily dictated by the temperature required for the pre-emergence development (Danks and Oliver, 1972). The emergence pattern of a sub-alpine dragonfly- Somatochlora semicircularis, has been found to be strongly synchronized, shortened and restricted to a single seasonal peak, possibly as a result of the pond drying up early in the season at high altitude (Willey, 1974). The emergence period of three species of Lestidae (Zygoptera) in North Carolina, United States of America, were temporally separated to a degree, a factor that is probably important in reducing competition in areas of coexistence (Ingram, 1976). Data on the life history of the emperor dragonfly Anax imperator revealed that two factors extend the duration of the larval stage, i.e. a high 'lower temperature threshold' for growth and a diapause in the final instar (Corbet, 1957). Studies on the life-cycle of the ephemerids Leptophlebia vespertina and L. marginata in a oligotrophic North Wales lake showed that both species are univoltine and growth continues throughout the winter although somewhat retarded (Brittain, 1972). In a woodland tarn in Sweden, several ephemerid species were reported to have best growth under condition of abundant food and high temperatures (Kjellberg, 1973). Life cycles of Heptagenidae in Wisconsin, United States of America showed nineteen species having univoltine cycles while two and possibly a third had bivoltine cycles (Flower and Hilsenhoff, 1978). A multivoltine mayfly Trichorythodes minutus in a location having a spring source and relatively constant temperature was found to be bivoltine in another location with normal seasonal fluctuations in water temperatures (Newel and Minshall, 1978). In an association of Odonata, Kormondy and Gower (1965) observed that considerable annual variation existed in each species in the onset, peak and duration of emergence periods; the degree of synchrony of emergence; population size and sex-ratio. However, these variations showed no consistent pattern of alternation among the different species suggesting plasticity of response to differential influences. Great interspecific variation was also observed in the life history pattern of four hydropsychid caddisflies situated in a Montana lake (Oswood, 1976). Species differed considerably in overwintering stage and showed some divergence in the timing of pupation and adult emergence. It was suggested that temporal separation of life-cycle events is probably significant in enabling several species of Zygoptera to co-exist (Ingram, 1976; Ingram and Jenner, 1976). Studies on annual production of Corixa germari (Fieb) in an upland British reservoir, suggested wave action and predation to be important causes of adult and nymph mortality (Crisp, 1962). Macan (1965) observed that although the total number of species of water bug was lower after the introduction of fish, it was never high even when there were no fish. He therefore concluded that absence of predation is not one of the main reasons why some pieces of water harbour many species. Applegate and Kieckhefer (1977) also held the view that corixids were not the prey species of the common littoral zone fishes and thus fish predation had no known significant effects on corixid population dynamics. On the other hand, Eriksson et al (1977) observed that there were more species of Notonecta and Corixidae in lakes without fish when compared with lakes with fish population and the difference was significant. Thus predation pressure from fish may be a limiting factor to water boatman populations. Investigation on the population of Gerris najas (Heteroptera) showed overwintering mortality which averaged 80% (Brinkhurst, 1966). It was found that control of population of Gerris remigis (Heteroptera) results mainly from winter mortality of the adults and from cannibalism, the latter acting at the level of the larvae (Matthey, 1976a). It was also postulated that primary cause of the nymphal mortality of *Notonecta hoffmanni* is a reduction in food availability resulting in increased cannibalism. Reduction in spatial refuges also influences cannibalism rates (Fox, 1975a). Cannibalism occurred when there was physical proximity between age-classes even if alternative food were abundant (Fox, 1975b). Population data of two corixid species living in temporary rock pools showed similar reproductive phenology, total qualitative habitat overlap and frequent occurrence of harmfully high densities during the reproductive period (Pajunen, 1979). In the unpredictable rock pool environment the inferiority of the smaller *Callicorixa producta* is offset by its ability to disperse rapidly into refilled pools after the termination of rainless period. It was observed that larvae of damselfly *Pyrrhosoma nymphula* made pronounced movements during development resulting into complete separation of senior and junior age-classes into different areas of the pond (Lawton, 1970). This is suggested to be important in preventing predation by large larvae on smaller individuals. It was also indicated that neighbouring imaginal damselfly population between which there is little interchange may each have their own specific survival rates, which may be largely determined by the geographical features, vegetation and specific predators and which are not directly related to the numbers of imagines present (Parr, 1972). Physiological condition was found to be more important in controlling numbers than male intra-specific interactions in the damselfly *Enallagma cyathigerum* (Parr, 1976). Studies on dry to wet seasonal changes in Mexican Anisoptera revealed that while some species were present in the dry season and increasing in numbers in wet season, others were confined to the wet season only (Dunkle, 1976). It was hypothesized that the number and size of the species of zooplankton present is important in determining which Chaoborus species are present (von Ende, 1973). High larval density of Aedes albopictus in Nagasaki in mid-summer resulted in heavy mortality and delay in development (Mori and Wada, 1978). Studies in several lakes such as Lake West Okoboji (Clampitt et al, 1960), Lake Chad (Dejoux, 1969) and Lake Warniak (Wojcik, 1970) recorded Chironomids as the most abundant group. Chironomidis were also found to be the dominant forms in a study on emerging insects from four small lakes in the south and south-west of Ireland (Bracken and Murray, 1973). A higher standing crop of Chironomid fauna was also recorded in a tropical man-made lake, in areas under the direct influence of the inflowing rivers (Petr, 1971). It was presumed that this is due to the inflow of allochthonous organic material during floods. Abundance of most Chironomidae and Tanypodinae within the Canadian subarctic bay increased in areas with reduced oxygen concentration, while several other species developed large populations in only deep well-oxygenated water (Moore, 1979). In a recent study (Beattie, 1982) it was observed that density and biomass distribution of larval Chironomids depended generally on the substrate type and its stability.

In many studies from different parts of the world, attempt was made to correlate the abundance, distribution, seasonal fluctuations and life-cycles of aquatic insects with biotic and abiotic factors of the environment. Temperature, amount of vegetation, shading of water surface, shore margin profiles and nature of the soils or soil forming materials adjacent to the water, seemed to have an effect on the abundance of four species of aquatic beetles of the genus *Laccophilus* (Zimmerman, 1960). It was revealed that several species of aquatic insects showed preferences for certain aquatic plants and soft wood trees (Petr, 1968, 1970a). On the other hand, dead branches with a loose layer of bark were the preferred substratum for two species of aquatic Coleoptera *Helodes marginata* and *Helodes minuta* (Rasmussen, 1978). Fallen leaves were found to be the primary food source of insect communities in a small Quebec stream and where this habitat predominated the greatest number of species were recorded (Mackay and Kalff, 1967). The variety of the species apparently depended on the diversity of the habitat, stability of the substrate and availability of food. That increased eutrophication can lead to the disappearance of some species of Ephemeroptera was indicated (Morgan, 1970). Detritus was found to be a significant factor in explaining variation in the density of benthic insects (Brittain, 1978; Kaster and Jacobi, 1978). Voshell and Simmons (1978) reported that physical factors which determines the success of Odonates during transition from lotic to lentic ecosystems are the rate of flow, vegetation and bottom composition. The quantitative and qualitative changes in the benthic insects in Volta Lake, Ghana seem to be determined to a large extent by changes in the substratum due to shore line erosion resulting in translocation of fine mud particles into deep water and in the destruction of the littoral vegetation (Petr, 1974). Type of substrate, amount of organic matter present, dissolved O_2 concentration, pH, temperature, supply of allochthonous matter, water level, food supply, prevailing wind and degree of water agitation were found to influence the seasonal abundance and distribution of various species of aquatic insects (Petr, 1972; Hongve, 1975; Mackey, 1976; Fiance, 1978; Ferguson and Fox, 1978; Campbell and Denno, 1978; and Bidwell, 1979). Experimental studies on aquatic insects indicated that temperature is a major factor in regulating the changes in nymphal growth rate (Nebeker, 1971; and Brittain, 1976). In the region of Kananaskis, Alberta, Canada at 1600m above sea-level, the presence or absence of permanent population of Gerris remigis on ponds depends on water temperature which in turn determines the rate of development of the eggs and of the larvae (Matthey, 1976b). Seasonal fluctuation of immature stages of several species of mosquitoes and midges were found to be closely related to rainfall (Ho *et al*, 1971; Ali *et al*, 1977). Strong correlation was also observed between the precipitation and the distribution of tree-hole mosquitoes (Lunt and Peters, 1976).

Although the taxonomy of Indian aquatic insects have been dealt by a good number of workers (Distant, 1903; 1906; 1910; Nowrojee, 1911; Laidlow, 1920; Fraser, 1933; 1934; 1936; Hutchinson, 1940; Vazirani, 1955; 1964; 1968; 1970; Sangal and Kumer, 1970a; 1970b), available literature on their ecology is comparatively meagre. Annandale (1919) was the earliest worker to study the ecology of aquatic insects in India. Hora (1923, 1927, 1930) made detailed study on the adaptation and ecology of aquatic insects of torrential streams. Hydrophilid beetles were recorded from a hot spring in Kulu Valley, Punjab (Pruthi, 1939). The occurrence of insects at salinities ranging from 0.96% to

16.4% in the Sambhar Lake, Rajasthan was reported (Baid, 1959). The seasonal abundance of aquatic bugs in Poona area, Western India in relation to environmental factors was discussed (Tonapi, 1959). The general composition of aquatic beetle fauna of Poona was found to be predominated by members of Dytiscidae and Hydrophilidae. A close relationship of the volume of the water and the beetle fauna contained in it has also been noticed (Tonapi and Ozarkar, 1969; 1970). The food and feeding habits of the bug <u>Anisops bouvieri</u> was studied by Gorai and Roychaudhuri (1963). Julka (1965, 1969) made detailed observations on the aquatic bugs injurious to pond cultured fishes. Julka (1977) further recorded his observations on the seasonal fluctuations in the population of aquatic bugs. He indicated that temperature, rainfall and migration are factors contributing to these fluctuations. Kumar (1972) studied the seasonal distribution of dragonflies around different types of larval habitats in the DehraDun Valley. He pointed out that in the species developing in perennial streams, the larval period is prolonged for some 5-8 months, while the adults are on the wings for not less than 3-4 months. On the other hand, the larval period of species breeding in seasonal monsoon ponds is shortened to about 2-4 months, while their adult life-span is prolonged to 8-9 months. The distribution and behaviour of Odonata around a freshwater lake was also discussed by Kumar (1978). Rao (1976) made a comparative study of the biological and ecological aspects of four species of aquatic Hemiptera belonging to the family Nepidae. It was observed that the total volume of the benthos from a freshwater pond at Burdwan, West Bengal, fluctuated markedly with an unimodal pattern of distribution while the peak was recoro and the trough in January (Mandal and Moitra, 1976 sonal abundance of aquatic Hemiptera and Coleoptera Kumaon lakes was discussed in relation to physicochem para-meters of water (Das and Bisht, 1979). Bisht and Das (1980) put forth the view that the predominance of predatory bugs causes more destruction to fish juveniles than the aquatic beetles in a coldwater fish tank.

For the study of dispersal, captures of aquatic insects at light have been reported from many parts of the world. These records have been summarised by Fernando (1958, 1959, 1961). At Rothamsted Experimental Station, Hemiptera-Heteroptera were taken in light traps during the four years 1933-1936 (Thomas, 1938). Details of the 'Rothamsted Light-Trap' was discussed by Williams (1948). In later years, various types of light traps have been used. Yamamato (1951) recorded his observations on the phototropic response of aquatic beetles to the fluorescent light traps. The 'Pennsylvania insect light trap' has proved outstanding and has been used as a standard for comparison with other traps (Frost, 1957). Test of incandescent, mercury vapour, cool white and black fluorescent lamps in insect-traps (Heath, 1966; Belton and Pucat, 1967) have shown that black light is a superior attractant for various insects and leads to the capture of an abundance of individuals and representatives of many species. Ultraviolet light-traps were found to be effective for sampling many types of insects that are dusk active such as caddisfly adults (Corbet and Tjonneland, 1955; Ulfstrand, 1970). Comparison of insect catches in a blended and a black light-traps were made in Northern Finland (Blomberg et al, 1976). The influence of light and temperature on the migration of Corixidae was analysed (Popham, 1942, 1953). The limitations of light traps have been discussed (Popham and Landsbury, 1960). Fernando (1961a) pointed out that flight of aquatic insects at night is a widespread phenomenon all over the world and is an integral part of the normal colonization cycle. He also gave a comprehensive bibliography of records of insects at light. It was revealed that, in general the species taken at artificial light are more widely distributed than the other species in the area. It was also suggested that regular monsoonal winds and storms play an important part in the dispersal of small species over long distances seasonally. The larger species fly considerable distances (Fernando, 1961b). Fernando (1963) further recorded aquatic insects taken at light in various parts of Asia, while Petr (1970b) recorded Chironomidae attracted to lights on the research vessel 'Tilapia' in the man-made Volta lake, Ghana. In a light trap in Sinaia, Rumania, of the total insects captured 97.3% were Diptera (Albu, 1971). In India, Jeyasingam et al (1974) made light trap experiments in Madurai area and observed that hemipterans were more predominant than coleopterans. Light trap experiments in three Ivory Coast rivers showed that except for Caenidae, Tricorythidae and Leptophlebidae, all species of Ephemeroptera exhibited flight activity at the beginning of the night (Elouard and Forge, 1978). The influence of certain weather factors on the catches varied with the type of lamp. Increased cloudiness and higher minimum temperatures tended to raise the catches of the mercury vapour light to a greater extent than those of the UV light, whereas increased wind velocity caused a more marked decrease in the catches of the mercury vapour light (Blomberg <u>et al</u>, 1978). Koskela <u>et al</u> (1978) observed great variation in the number of mosquito species during different summers. It was also observed that minimum and maximum air temperatures influences not only the number of species and individuals of caddisfly, but also the proportion of male <u>Hydropsyche oslari</u> (Resh and Sorg, 1978). In a recent study, Zalom <u>et al</u> (1979) observed that seasonal variations in date of initiation of flight, relative abundance of individuals and time of peak flight activity existed among several species of Hydrophilidae.

Macan and Kitching (1972) initiated some experiments with artificial vegetation made of polypropylene rope, to see how similar is the fauna in two identical vegetation and how does the fauna of artificial compare with that of natural vegetation. They concluded that artificial vegetation can give a picture of the composition of animal communities if sampling of the real vegetation is also carried out concurrently. On the other hand, it appears to provide useful means of making various comparisons. Macan (1976) further used artificial vegetation for his studies on the water bugs in a moorland fish pond. Not much further work has so far been reported in literature after those pioneering experiments.

The predatory propensities of aquatic insects have been revealed in a number of early studies (Hungerford, 1919; Champlair 1923; Wilson, 1923). It was observed that backswimmers often attack mayfly, damselfly and dragonfly naiads many times their own size (Lucas, 1908; Essenberg, 1915). The larger notonectids have also been known to prey upon tadpoles and small fish (Imms, 1951). Among the Indian workers, Khan and Hussain (1947) recorded their observation on the destruction of carp fry by larvae of insects. Alikunhi et al (1955) demonstrated that effective control of aquatic insects enhances the survival of fish fry in nurseries considerably. It was reported that Nepa, Dytiscus and Cybister cause heavy damage in nursery tanks while Ranatra was less harmful (Ganguly and Mitra, 1961). Studies on Notonecta glauca showed that the notonectids would be pests in the pond culture of various cyprinids, as well as for the larval stages of fish species living in natural, small, shallow still water habitats (Dahm, 1972). Rise (1975) observed that the great diving beetle Dytiscus marginalis has a voracious appetite. He calculated that if a pair of Dytiscus arrive at a fish hatchery pond, the 100 or so larvae they produce will consume 27,500 young fish 2-3 cm in length by the time they pupate. Studies concerning prey-predator relationships among aquatic insects has been reviewed by Bay (1974). In a number of studies in recent years it was shown that aquatic insects like odonates (Pritchard, 1965; Service, 1965), hemipterans (Ellis and Borden, 1970) and coleopterans (Christophers, 1960) can play an important role in the biological control of mosquitoes. Laboratory studies on the predacious habits of the dragonfly nymphs showed that Brachytron pratense have special affinity to feed on Culicid larva and pupa (Hati and Ghosh, 1965). Ellis and Borden (1970) found that the adults of Notonecta undulata preferred mosquito larvae to other aquatic invertebrates. They suggested that selection of prey might be affected by the behaviour, palatability, mobility and motility of the prey types. Gittelman (1974) conducted a prey preference test for Martarega hondurensis and found that the backswimmer preyed on ants struggling at the water surface in preference to corixids, mosquito larvae and pupae, blood worms and ostracods. When offerred a similar selection of prey types, Buenoa antigone responded by taking mosquito pupae and ants. Mathavan (1976) showed that the dragonfly nymph Mesogomphus lineatus is well suited for the capture of mosquito larvae and pypae. It was indicated that maximum food intake of the nymph is significantly dependent on weight as well as temperature (Pandian et al, 1979). Changes in the volume and depth of water in aquarium considerably influence the predatory behaviour of M. lineatus (Mathavan and Jeyagopal, 1979). However, Prakash and Ponniah (1978) observed that the predatory capacity of the carnivorous mosquito Lutzia raptor is not influenced by changes in volume of water, but significantly influenced by changes in prey-density. Larvae of damselfly Ischnura elegans (Odonata) was found to consume different prey items in roughly the same proportion as their occurrence in the field (Thompson, 1978a). It was tentatively suggested that no prey size selection occurs by Ischnura larvae within the size range that they are capable of dealing with (Thompson, 1978b). Field and laboratory observations on eight species of Arizona backswimmers revealed that although each is capable of utilizing many available food types, certain prey organisms are selected when an assortment is presented (Zalom, 1978a). A comparative study on two species of backswimmers indicated that with respect to quantifiable feeding patterns, species of Notonecta differ from Buenoa in showing higher predation rates, shorter prey handling times and less food obtained from each prey (Zalom, 1978b). Gut content examinations of the hydrophilid larvae belonging to *Hydrophilus triangularis* and *Tropisternus lateralis* showed that predation was influenced not only by the relative size of the predator and prey but also by the availability of prey (Zalom and Grigarick, 1980).

S T U D Y   A R E A

The State of Meghalaya lies between 25°47' and 26°10'N and 89°45' and 92°47'E in North-Eastern India. The altitude ranges from 100 m at the foothills of Assam to 1950 m. The State covers a land surface of about 22,500 sq km and consists predominantly of a hilly terrain with narrow valleys in between and strips of plain land in the south-west and the north. It is bounded on the north-west, north-east and south-east by the State of Assam and on the south-west by Bangladesh. Thus the entire area within this State has undulating hills and steep slopes dissected by a network of rivers and their tributaries presenting a picturesque, wavy landscape. The present investigation was carried out in lentic water bodies of the Khasi and Jaintia Hills in the Meghalaya State. A part of the study was also carried out at Gauhati in the Brahmaputra valley of Assam State (Fig. 1).

Physiography :

From the physiographical point of view, Meghalaya represents a remnant of an ancient plateau of Pre-Cambrian Indian peninsular shield block raised to its present height. The kernel of the plateau is the exposed Archean gneisses and schists covered in this area by Pre-Cambrian quartzites and phyllites. This ancient peneplaned surface of the plateau is still preserved with marks of different cycles of denudation.

The soils of the study area are mostly lateritic in origin and vary from sandy loam, red loam to clay loam. It is generally acidic in nature, comparatively rich in organic matter and nitrogen but poor in phosphorus and medium in potash content (Agriculture in Meghalaya, 1977).

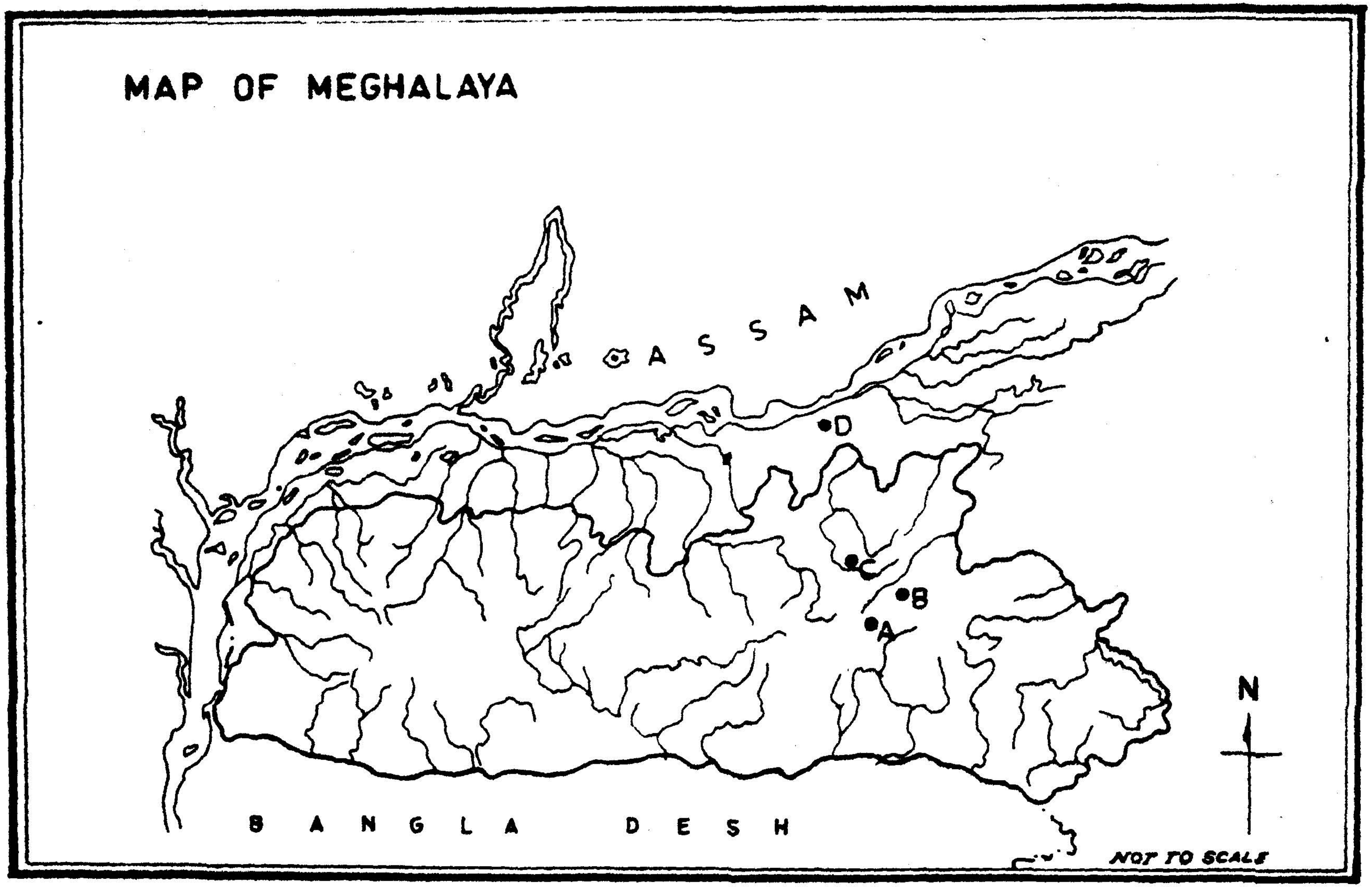


Fig. 1

Climate :

The area under study experiences a subtropical monsoon climate, with high rainfall (Table-I). The average rainfall recorded in Shillong, the capital of Meghalaya, reaches around 205 cm, while the maximum annual average of 1143 cm has been recorded from the nearby places of Cherrapunji and Mawsynram, the latter now being the world's rainiest place. The summer tempperature has been recorded as high as 28 C, while the winter temperature goes as low as 6 C. The winter is usually accompanied by ground frost at night and early morning hours. Situated in the plains of Brahmaputra valley, Gauhati is comparatively warmer than the Shillong area especially during the summer months. The summer temperature here reaches as high as 34 C, although the high temperature is often quenched by abundant rainfall.

On the basis of temperature regimes, each annual cycle could be divided into four seasons in the present investigation. They are :

(i) Spring --- March to April
(ii) Summer --- May to August
(iii) Autumn --- September to November
(iv) Winter --- December to February

Vegetation :

The vegetation of Meghalaya has been categorised under tropical and temperate types. The tropical vegetation is confined to elevation up to 1800 m and comprises of :

(i) Tropical evergreen and semievergreen forests along the high rainfall area of the southern belt; important plant species

TABLE-I

Rainfall data of Shillong and Gauhati

1978		Shillong	Rainfall (mm)	Gauhati
April	-	84.4	-	-
May	-	208.3	-	-
June	-	460.1	-	-
July	-	245.2	-	308.8
August	-	193.0	-	238.0
September	-	246.4	-	232.2
October	-	50.6	-	32.2
November	-	20.4	-	42.1
December	-	00.0	-	00.0
1979				
January	-	01.2	-	01.3
February	-	25.7	-	10.6
March	-	11.7	-	8.2
April	-	136.5	-	71.1
May	-	56.1	-	208.8
June	-	354.5	-	237.7
July	-	512.0	-	355.3
August	-	127.0	-	070.6
September	-	352.0	-	150.1
October	-	-	-	105.2
November	-	-	-	19.7
December	-	-	-	48.0
1980				
January	-	-	-	00.0
February	-	-	-	46.6
March	-	-	-	63.4
April	-	-	-	107.8
May	-	-	-	281.3
June	-	-	-	413.7

includes Castanopsis indica, Pterospermum acerifolium, Schima wallichii and Quercus spicata.

(ii) Tropical deciduous forests occupying a major portion of the state and include such economically important species as Tectona grandis, Shorea robusta, Pterocarpus marsupium and others.

(iii) Subtropical pine forests over the high altitude of Khasi and Jaintia Hills with Pinus kesiya as the chief element. Other species include Schima wallichii, S. khasiana and Myrica esculenta.

The temperate forest of Meghalaya are chiefly confined to elevations between 1800 m to 1950 m. The dense patch of 'Sacred forests' at Shillong peak and Mawphlang represent the true temperate forests, which include species such as Quercus griffithii, Photinia notoniana and Eriobotrya japonica.

The forests in Meghalaya have suffered from heavy deforestation activities, mainly due to the wasteful practice of the so-called 'Jhumming' or shifting cultivation, which involves cutting down and burning of forests. Subsequently a primitive form of agriculture is practised for a period of 2-3 years and then fallowing the area. It can be said that there is hardly any area in Meghalaya barring the sacred groves, which has not been jhummed at one time or other, with the result that luxuriant forest covered hills of one time are now rendered as grassland and barren areas.

Agriculture and Fish-Farming :

Agriculture is the mainstay of the people of Meghalaya. About 85% of the population live in rural areas and depend on agriculture for their livelihood. About 200,000 hectares of land in the state is presently under cultivation. Paddy is the major food crop of the state and rice is the staple food. It is grown throughout the state ranging from plain areas bordering Assam and Bangladesh to high altitude regions of about 1800 m. Other food crops includes: maize, wheat, millets and pulses. Potato is the major cash crop, specially in the central plateau of East and West Khasi hill districts. In many places, along with potato many other vegetable crops like cabbage, cauliflower and carrot are also grown.

In Meghalaya, fish-farming is next in importance to agriculture. However, the development of fishery in the state is far from satisfactory. The state is endowed with immense water resources comprising of about 5303.24 ha of ponds, tanks, lakes, reservoirs, beels and innumerable stretches of rivers and streams (Annual Plan Report of Meghalaya State Fishery Department, 1980). Of this, about 1775.44 ha are at present used for fish culture. But only 21.60 ha are under proper management. The State Fishery Department maintains a good number of ponds at several fish farms in Khasi and Jaintia Hills and these are: Fish Dale Farm (Shillong Mawpun Research Centre (Mawpun), Nayabunglow Fish Farm (Umsning), Kyrdemkulai Fish Farm (Kyrdemkulai), Ladthalaboh Fish Farm (Jowai) and Thadlaskein Fish Farm (Jowai). The private owned ponds are usually small in size, mostly perennial, though a few are of seasonal nature. Usually in winter, the water level of ponds is at the minimum due to heavy seepage as well as evaporation. As regards the seasonal ponds, they get filled up from the middle of May with the setting in of the monsoon rains and this water is retained till December-January. In general, the following species of fishes are cultured in various parts of the State: Labeo rohita, Catla catla, Labeo gonius, Cyprinus carpio, Labeo calbasu, Cirrhinus mrigala, Puntius sarana, Wallago attu, Clarius batrachus, Heteropneustes fossilis and Channa spp.

Sampling Sites for Population Study :

The systems chosen for population study are four fish ponds located in four different fish farms and at different altitudes. These are: Fish Dale, Shillong (1,550 m), Mawpun Fish Farm (1,100 m), Kyrdemkulai Fish Farm (820 m) and Ulubari Fish Farm at Gauhati (60 m). All the four systems are man-made nursery ponds used in pisciculture.

Fish Dale Pond :

It is a rectangular pond in the Fish Dale Complex of the State Fishery Department, located in the Fruit Garden Locality of Shillong (Pl. 1a). The pond has a length of 16.0 m and a breadth of 12.0 m. The total surface area is 215.0 sq m. The mean depth of the pond is 0.8 m. On one side, the pond is bounded by a cemented wall, while the other three sides are surrounded by nursery ponds. These ponds are interconnected by inlets fixed at one end of the pond. The aquatic vegetation of the pond includes: Juncus prismatocarpus, Hydrilla verticillata, Rotala rotundifolia, Drymaria cordata, Leersia hexandra and Spirogyra sp.

Mawpun Fish pond :

This pond belong to the Fishery Research Centre, Government of Meghalaya located at a place called Mawpun about 23 km north of Shillong (Pl. 1b). It is rectangular in shape with a length of 13.0 m and a breadth of 9.0 m. The total surface area of the pond is 131.0 sq m. The mean depth of the pond is 0.75 m. The pond is surrounded by hillocks on its northern and western side. The entire area is almost devoid of any vegetation excepting few herbs and grasses. The aquatic flora is also quite meagre and includes : *Rotala rotundifolia*, *Leersia hexandra* and *Limnophilia* sp.

Kyrdemkulai Fish pond :

This nursery pond is located in the Government Fish Farm at Kyrdemkulai near the Nayabunglow township, about 35 km from Shillong (Pl. 2a). The rectangular pond is 19.0 m long and 7.0 m wide, with a surface area of 145.0 sq m. The mean depth of the pond is 0.55 m. It is surrounded by other nursery ponds on two sides and is interconnected. The entire area is on a slight slope and at a depression from the surrounding area which has thick deciduous forests. The pond has a rich undergrowth of vegetation which includes : *Leersia hexandra*, *Rotala rotundifolia*, *Hydrolea zeylanica*, *Osbeckia nepalensis*, *Limnophilia* sp., *Arundinella bengalensis*, *Moneira cuneifolia*, *Schoenoplectus mucronatus*, *Isachne miliacea*, *Eragrostis unioloides*, *Aegeratum conyzoides*, *Hypericum japonicum*, *Sphaerocaryum* sp., and *Centella asiatica*.

Ulubari Fish pond :

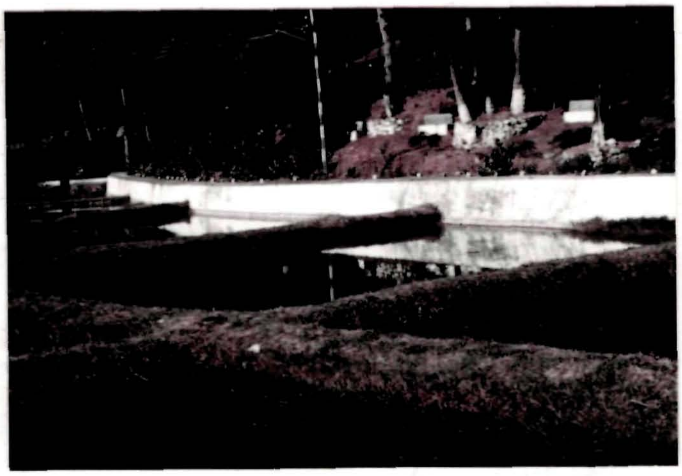
This pond is situated in the Fish Farm of the Assam

Government at the Ulubari locality of Gauhati about 103 km from Shillong (Pl. 2b). The pond has a length of 16.0 m and a breadth of 13.0 m with the total surface area being 225.0 sq m. The mean depth of the pond is 1.0 m. The pond is devoid of an inlet or outlet. There are other nursery ponds surrounding the three sides. The aquatic vegetation includes : Ludwigia actavalis, Gnaphalium indicum, Eclipta alba, Alternanthera sessilis, Hydrolea zeylanica, Lindernia sp., Rotala rotundifolia, Sphaeranthus indicus and Jussieua linifolia.

Sampling Sites for General Survey :

The general survey was carried out in 20 lentic systems. At one end of the spectrum 8 of these systems are located in and around greater Shillong (Lat. 25°34' N and Long. 90°56' E) area, at altitudes ranging from 1400 m to 1800 m, while at the other extreme, the system in the plain areas are located at altitudes ranging from 70 m to 100 m. These systems include lakes, man-made ponds, managed fish ponds, water bodies of natural occurrence and rain pools.

PLATE - 1



a

b

Plate 2 : Showing the sampling Stations 3 and 4.

(a) - Station 3 (Kyrdemkulai Fish pond)

(b) - Station 4 (Ulubari Fish Pond)

PLATE - 2

a

b

M A T E R I A L S   A N D   M E T H O D S

1. Population Studies :

The materials for the population studies were collected from four nursery ponds, namely - Fish Dale pond (Shillong), Mawpun Fish pond, Kyrdemkulai Fish pond and Ulubari Fish pond (Gauhati). In the Fish Dale pond, the study commenced from the month of April '78 and was continued till September '79. Further study could not be carried out in this pond, as it was dewatered subsequently by the Fishery Department, Government of Meghalaya. In the other three nursery ponds, the study commenced from July '78 and continued for a period of two years. While the Fish Dale pond and Mawpun Fish pond were stocked for a few months with fries of *Cyprinus carpio*, the Ulubari Fish pond was stocked with fries of *Heteropneustes fossilis*, also for a few months. The Kyrdemkulai Fish pond was not stocked with any fish. For the physico-chemical and biological studies, sampling was done at fortnightly interval during the first annual cycle; however, in the second cycle sampling was done at monthly interval. All the collections were made between 7.00 am and 10.00 am on each sampling date. Water samples were collected by slowly dipping a plastic bottle of one litre capacity just below the water surface. Chemical analysis of various factors were carried out immediately after the collections were over.

The air and water temperatures were measured using a mercury-bulb thermometer graduated from 0°C to 100°C. Water temperature was recorded by dipping a thermometer just below the water surface. The pH was measured in the field using a portable Lovibond '1000' Comparator. Dissolved oxygen, free carbon-dioxide and alkalinity were estimated using Standard Methods according to APHA (1965). Besides the above factors, rainfall, maximum and minimum air temperature data were collected from the meteorological stations at Shillong and Gauhati.

Sampling of aquatic insects was done with a rectangular pond-net having an opening of 24 cm long and 20 cm wide and netting with 1 mm mesh. In each pond, insects were sampled at four predetermined areas representing the four sides of the pond. Samples were taken by sweeping the net over a distance of 1 m. Four such sweeps form a single integrated sample. Effort was made to keep the sampling procedure constant throughout the period of study. Samples were preserved in 6% formalin. In the laboratory, samples were analysed and organisms identified as far as possible and grouped into species or higher taxonomic categories. In each group the number was counted. To estimate the standing crop (biomass), specimens were placed for about 3 minutes on blotting paper, to remove excess moisture, weighed on a torsion balance to the nearest of 0.2 mg.

2. Light-trap Studies :

The light-trap studies were conducted in the Fish Dale, Shillong for a period of 10 months, during March '78 to December '78. The trap consisted of one petromax light and nine white enamel trays each of size 32x27 cm, making a total trapping surface of 96x81 cm. The light source was of 400/500 candle power. The insects attracted to the light fell in the water placed in the enamel trays surrounding the light source. Detergent added to water, made the insects sink and prevented them from drifting to the edges for escape, narcotising them at the same time. Teepol was used as the detergent.

Trapping was done on new-moon day every month, thus avoiding the effect of moonlight on the catch. One of the enamel trays was put upside down on the ground in a selected area which is surrounded on all the sides by nursery and rearing ponds. The petromax light was placed over this tray. Around the base tray of the petromax light, the other eight well cleaned white enamel trays were placed. Care was taken to put all the trays on the same plane. 5cc of Teepol was added to each tray which was half-filled with water and thoroughly mixed. The total duration of the experiment was for a period of 12 Hrs. (1800 to 0600 Hrs). At every 2-hourly interval, the samples were collected by pouring the water from the trays along with insects caught through a fine muslin cloth in a bucket and the water reused. A uniform light was maintained by pumping the petromax light every 2 Hrs. Care was also taken to avoid the blackening of the glass enclosing the light source. The light source was protected from the rain during the rainy season by mounting an umbrella over the trap. At the times of heavy rains two or more umbrellas were used. The insects collected were preserved in 6% formalin. In the laboratory, they were sorted into species, genera or higher taxonomic groups and their numbers counted.

3. Colonization of artificial substrates by aquatic insects :

These experiments were carried out in Kyrdemkulai Fish pond and Ulubari Fish pond, for one annual cycle starting from July '79 to June '80. Artificial substrates imitating *Littorella* sp. and *Rotala rotundifolia* were used for the experiments. The artificial *Littorella* were made from 3-strand polypropylene rope and about 13 mm in circumference. I am grateful to Dr. T.T. Macan of the Freshwater Biological Association, Ambleside (U.K.) for a donation of this artificial Littorella. The lattice was of orange polythene shrimp netting with 11 mm space between knots. A length of polypropylene strand was doubled and the loop was passed round the side of one square of the lattice. The two free ends were passed through the loop and pulled tight. The resulting L (leaves) stood 7 cm above the lattice. The polythene squares measured 12.5x12.5 cm and took 72 knots when these encircled every other cross piece. This number of knots gave 144 leaves. A square with a knot round every cross piece had 288 leaves.

Artificial R. rotundifolia were also made of similar polypropylene rope mentioned above. A portion of the rope was cut into small pieces which were unravelled and given the shape of leaves by the application of heat. The leaves were tied into a length of polypropylene rope in such a way that they are placed on opposite sides, each facing another and are 1.5 cm apart. This length of polypropylene, when tied to a polythene square (12.5 x 12.5 cm) stood 32 cm above the lattice. Altogether, four such lengths of polypropylene, each resembling a R. rotundifolia plant, were tied to a lattice. They were tied in the polythene square in such a way that they stood at equal distance from the mid points of their nearest side. There were altogether 40 leaves in each length of polypropylene and a single leaf measure 15 mm in length.

Each unit of artificial Littorella and R. rotundifolia was placed in predetermined area of the pond. Flat stones, fitted into a pocket of fine netting beneath each square kept it on the bottom. Collections were made every month by lifting a square gently from the bottom and slipping a net underneath. Swirling in a basin of water (Macan and Kitching, 1972) removed the animals, and the square was then replaced. The animals so collected were preserved in 6% formalin. In the laboratory, they were sorted into various taxonomic groups and their numbers counted.

4. Predatory propensities of a dragonfly nymph :

Experiments on the predatory propensities of a dragon fly nymph were conducted at Shillong during April '79 to July '79 under laboratory condition.

Final instar nymph of the dragonfly *Orthetrum* sp. were collected from a nursery pond at Fish Dale, Shillong. The nymphs were maintained individually in aquaria having a capacity of 300 ml. They were fed with spawn (2-3 days old) of common carp *Cyprinus carpio*, for a period of 7 days to acclimate them to the test prey and to the laboratory conditiob. The spawns of *C.carpio* were brought from Fish Dale, Shillong on the day of the experiments and were kept in the laboratory in an aquarium (size 40x48 x40 cm). On some occasions, spawns of *C. carpio* were also brought from the Ulubari Fish Farm, Gauhati.

5. General Survey of aquatic insects in twenty lentic systems :

A general survey of aquatic insects was conducted during the period January to December '79 at twenty lentic systems. The sampling of insects was done as per method described for population studies. Samplings were made during the summer and winter seasons. Each of the system was visisted 2-3 times during both the seasons.

CHAPTER - I

P O P U L A T I O N   S T U D I E S

RESULTS

1. Physico-chemical characteristics :

The different physico-chemical parameters analysed at the four sampling stations were air and water temperature, pH, dissolved oxygen, free carbon-dioxide and alkalinity. The trend of fluctuation of these individual factors is dealt with for each station separately.

(i) Fish Dale, Shillong (Station 1) :

The physico-chemical parameters were analysed for a period of 18 months in this station. They are depicted in Figure 2.

The air temperature, recorded during the study period revealed that it was always higher than the water temperature except in April '79. The maximum air temperature was observed in July '78 with a value of 25.5°C, while the minimum value of 13.5°C was recorded in January '79. The surface water temperature as that of air temperature had similar fluctuations though of slightly lower magnitude with the maximum value of 24.5°C in July and with the minimum of 12.0°C in January. Distinct summer maxima and winter minima are observed in this station for both air and water temperatures.

The hydrogen ion concentration values indicated fluctuations only between the acidic range and slightly above neutral. In the first few months, there was very little variation in the pH, with the highest value of 7.1 recorded in July '78. In the subsequent months, there was a gradual decrease till January '79, when the value reached the lowest of 6.0. Thereafter, an upward trend was observed till a peak was obtained in June '79. As in temperature, pH also revealed summer maxima and winter minima, though the magnitude of variation was far less than in the former.

The dissolved oxygen ranged from a minimum of 5.6 mg/l at the beginning of the study period in April '78 to reach maximum of 9.2 mg/l in August. A similar trend of fluctuation was observed throughout the rest of the study period except that the peak during the second cycle was recorded in July '79.

The free carbon-dioxide indicated marked fluctuations ranging from a minimum of 3.2 mg/l to a maximum of 7.4 mg/l. The former was seen in February '79, while the latter was observed in June '78. A second peak was observed in May '79, which thereafter decreased.

Alkalinity values showed a decline from the maximum of 44.0 mg/l in April '78, the beginning of the study period till June '78, followed by an upward trend till a peak was attained in August '78, with 41.0 mg/l. This was followed by a decline of a minimum of 18.4 mg/l in January '79. In subsequent months a similar trend of bimodality was observed with peaks in April and August '79. Thus spring and autumn maxima were observed for this factor.

(ii) Mawpun Fish Pond (Station 2) :

At this station all the abiotic factors analysed were for a total period of two annual cycles. They are depicted in Figure 3.

The air and water temperatures and their trend of fluctuations were similar to Station 1. Here also a distinct summer maxima and winter minima was observed for both air and water temperatures and it was more or less repeated for both the annual cycles. However, there was slight variation in the magnitude of fluctuations. The maximum values of air temperature recorded in August and September '78 was 29.5°C while the minimum of 15.5°C was observed in February '79. The maximum water temperature of 30.0°C was recorded in July '79, while the minimum of 16.0°C was observed in February '79.

The pH values remained acidic throughout the period of investigation except in June '79, when it turned slightly alkaline. From the lowest value of 5.85 units in August '78 in the first year of study, pH showed an increase to attain a small peak in December, followed by a decrease till March, only to increase subsequently and reach a peak with the maximum of 7.2 in June '79. An almost similar pattern of fluctuation was seen in the second year with a peak in December-January. Lower values were recorded in October and April. Unlike Station 1, the pH values at this station showed a bimodality with summer and winter maxima and spring and autumn minima.

Similar to pH, the dissolved oxygen also showed bimodality with summer and winter maxima and spring minima, but the range of fluctuation was much higher than in the former. The value of 9.24 mg/l in July '78 in the beginning of first year declined steadily till October, after which it increased rapidly to reach the maximum value of 10.0 mg/l in December followed by a sharp fall. The downward trend continued till April '79, with the lowest of 6.6 mg/l. The second year recorded an almost similar trend with peak values in July '79 and January '80 and lower value in May '80. As in Station 1, the first cycle recorded both the maximum and minimum values for this factor.

Free carbon-dioxide values showed a trend of fluctuation different from Station 1. The first year recorded its peak in May '79 (5.6 mg/l) with the lowest value of 2.0 mg/l in December '78. The second year however, obtained the peak in March '80 with a maximum of 6.0 mg/l, while the minimum was seen in August '79. Thus the first year showed summer maxima with a winter minima, but the second year recorded spring maxima and autumn minima.

The alkalinity values recorded a slightly lower range than in Station 1, with a minimum of 10.0 mg/l and a maximum of 32.0 mg/l. Both the values were recorded in the first year, the minimum in October '78 and maximum in April '79. The values shifted slightly in the second year, with minimum in December '79 and maximum in May '80. However, the peak value in the second year was much lower than the first year (25.0 mg/l). A spring maxima and autumn minima in the first year, while a summer maxima and winter minima in the second year were recorded for this factor.

(iii) Kyrdemkulai Fish Pond (Station 3) :

As in Station 2, all the abiotic factors were analysed for a total period of two years. However, no collection could be made in this pond in the month of April '79, as the pond was almost dry. The seasonal fluctuations of the factors are depicted in Figure 4.

Air and water temperatures revealed the same trend of fluctuations as seen for Stations 1 and 2, with slight variations in their magnitudes. The maximum values of air and water temperatures were recorded in August '79 (31.5°C) and May '79 (32.0 °C) respectively. The minimum value for air temperature was recorded in December '80 (17.5°C), while a similar decline for water temperature was however recorded in January '79 and February '80 (15.0°C).

pH values were acidic during the entire period of study, ranging between a minimum of 5.6 and a maximum of 6.8. The first year recorded its peaks in September '78 and May '79, while in the second peaks were in September '79 and April '80, the latter being the maximum. The lowest value was recorded in January '79 and December '79 in the first and second years respectively. pH thus showed bimodality with autumn and spring maxima and winter minima for this station.

Dissolved oxygen reached a maximum of 10.8 mg/l in July '78 in the beginning of the study period, with a rapid fall subsequently. This downward trend continued till March '79 with intervening period of increase of lower magnitudes in October '78 and February '79. A small rise was indicated in May '79, followed again by sharp fall in June '79, to reach a value of 6.24 mg/l, the minimum for the first year. The second year recorded small peaks in September '79 (8.4 mg/l) and May '80 (8.0 mg/l), with the lowest of 6.0 mg/l in January '80. Thus while the maximum and minimum values were recorded during the summer in the first cycle, the maximum was recorded in autumn and the minimum in winter during the second cycle.

The fluctuations of free carbon-dioxide showed a trend different from Stations 1 and 2. Here the peak values were recorded in December '78 (10.2 mg/l) in the first year and October '79 (10.4 mg/l) in the second year, the latter being the maximum. The same minimum of 4.4 mg/l was recorded in July '78 and May '80, in the first and second cycles. A winter maxima in the first year and an autumn maxima in the second year were observed. However, both the years indicated summer minima.

Alkalinity values also indicated almost similar trend with winter and spring maxima in the first and second annual cycles respectively. As of carbon-dioxide, both the cycles showed summer minima, with the minimum value of 12.8 mg/l recorded in July '78 and June '80. The peak values however, were recorded in December '78 (24.4 mg/l) and March '80 (28.0 mg/l).

(iv) Ulubari Fish Pond (Station 4) :

All the abiotic factors in this station were recorded for a total period of two years. They are depicted in Figure 5.

As for other three stations, both the air and water temperatures revealed summer maxima and winter minima. The maximum values for the air and water temperatures were recorded in July (31.5°C and 31.0°C), while the minimum values were observed in January with 17.0°C and 15.0°C.

Unlike in the other three stations described earlier, pH value in this station remained alkaline throughout the entire period of study, ranging between 7.2 to 9.4 in the first year and between 7.2 to 9.0 in the second year. The maxima were recorded in April in both years. The minimum was noted in August and November in the first year and February in the second year. A spring maxima and summer and winter minima was seen in the first year, with a spring maxima and a winter minima in the second year.

Dissolved oxygen also indicated a similar trend, but the range of fluctuation was much higher than the pH. It ranged between 6.56 mg/l to 14.6 mg/l in the first year and between 7,08 mg/l to 14.0 mg/l in the second year. Maximum values were recorded in May '79 and April '80 of the first and second year respectively. The minimum values however, were observed in July '78 and October '79 of the first and second year respectively.

Free carbon-dioxide revealed a trend different from other stations, although the range of fluctuation was similar to Station 3. The values ranged between 5.8 mg/l to 10.4 mg/l during the first annual cycle and between 4.4 mg/l to 10.5 mg/l during second. Maximum was recorded in March '79 while the minimum in November '78 of the first annual cycle. A maximum in May '80 and minimum during December '79 was observed during the second annual cycle.

Alkalinity values recorded distinct winter maxima and summer minima. Maxima of 124.0 mg/l and 112.0 mg/l were recorded in February in both the annual cycles, while the minimum of 67.0 mg/l and 71.0 mg/l were recorded in June in the first year and May in the second year respectively.

Figure 2 : Showing the seasonal fluctuations of physico-chemical parameters at Station 1

△——△ CO_2

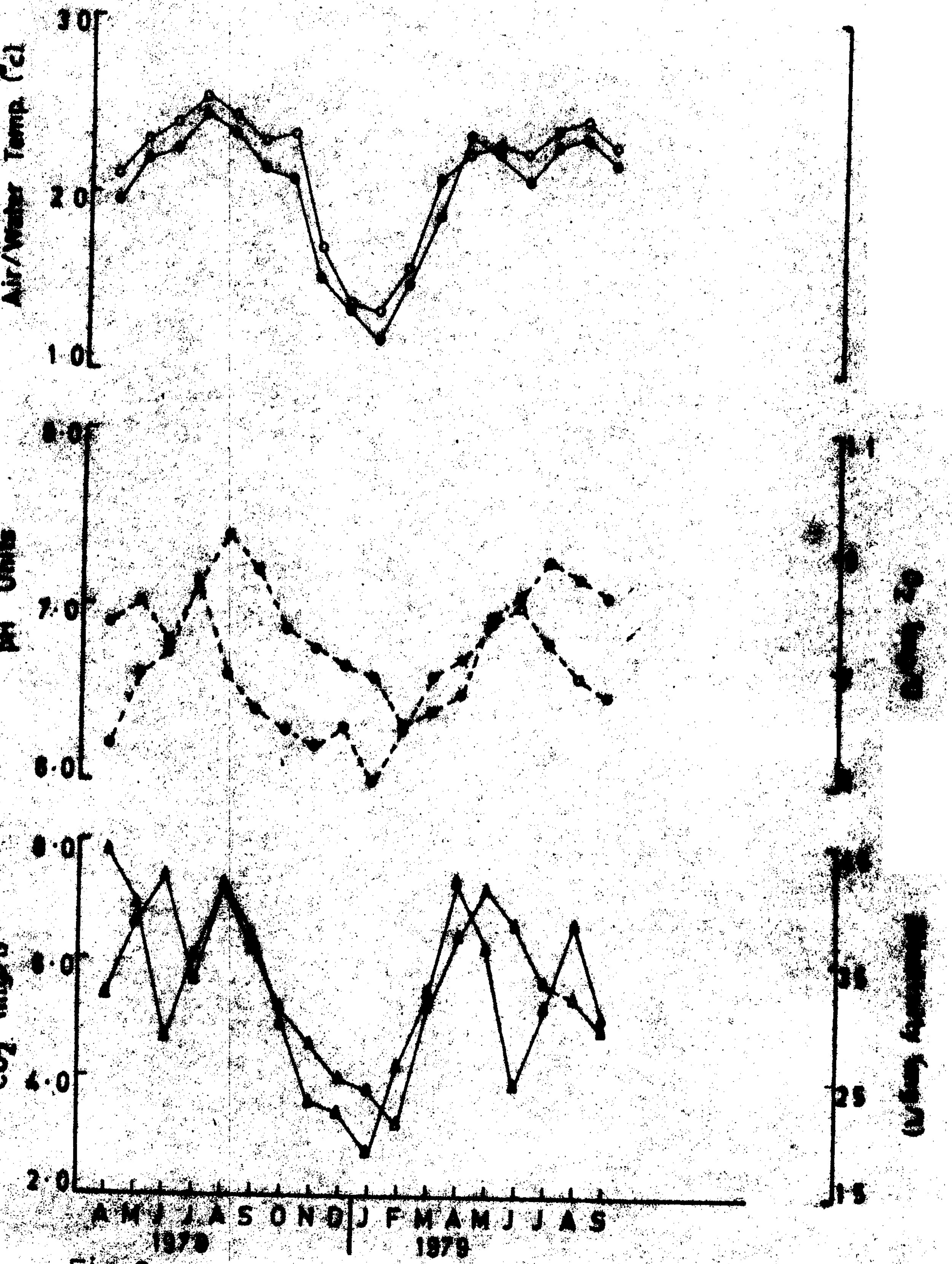
▲——▲ Alkalinity

o- - -o pH

●- - -● O_2

o——o Air temperature

●——● Water temperature



Air/Water Temp. (°C)
30
20
10
pH Units
8.0
7.0
6.0
CO2 (mg/l)
8.0
6.0
4.0
2.0
A M J J A S O N D J F M A M J J A S

Fig. 2

Figure 3 : Showing the seasonal fluctuations of physico-chemical parameters at Station 2

△——△ CO_2

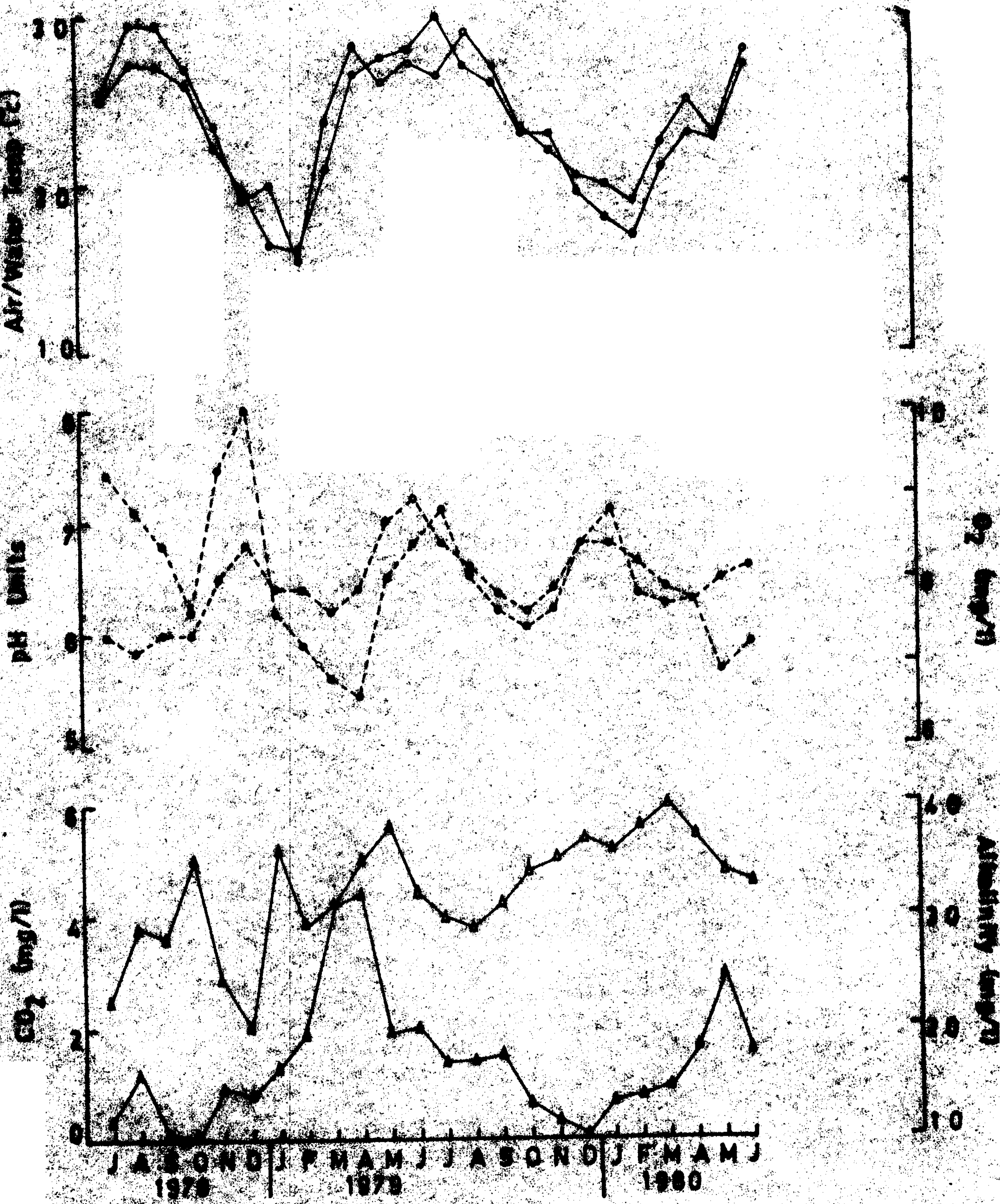
▲——▲ Alkalinity

○- - -○ pH

●- - -● O_2

○——○ Air temperature

●——● Water temperature



Air/Water Temp (°C)
30
20
10
pH Units
8
7
6
5
CO2 (mg/l)
6
4
2
0
40
30
20
10
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig.3

Figure 4 : Showing the seasonal fluctuations of physico-chemical parameters at Station 3.

△——△ CO_2

▲——▲ Alkalinity

○- - -○ pH

●- - -● O_2

○——○ Air temperature

●——● Water temperature

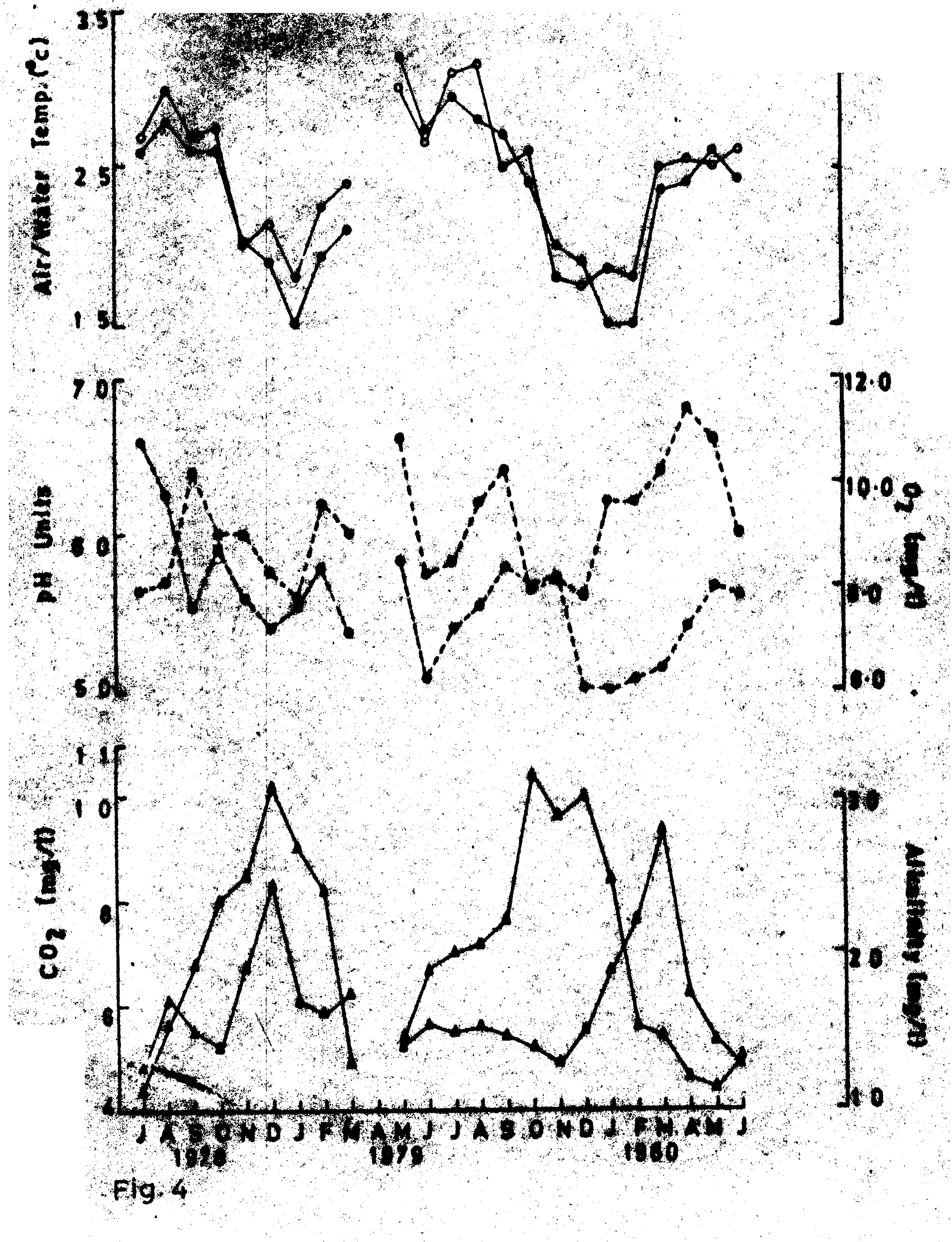

Air/Water Temp. (°C)
pH Units
CO2 (mg/l)
O2 (mg/l)
Alkalinity (mg/l)
J A S O N D J F M A M J J A S O N D J F M A M J
1979
1980

Fig. 4

Figure 5 : Showing the seasonal fluctuations of physico-chemical parameters at Station 4.

△——△ CO_2

▲——▲ Alkalinity

○- - -○ pH

●- - -● O_2

○——○ Air temperature

●——● Water temperature

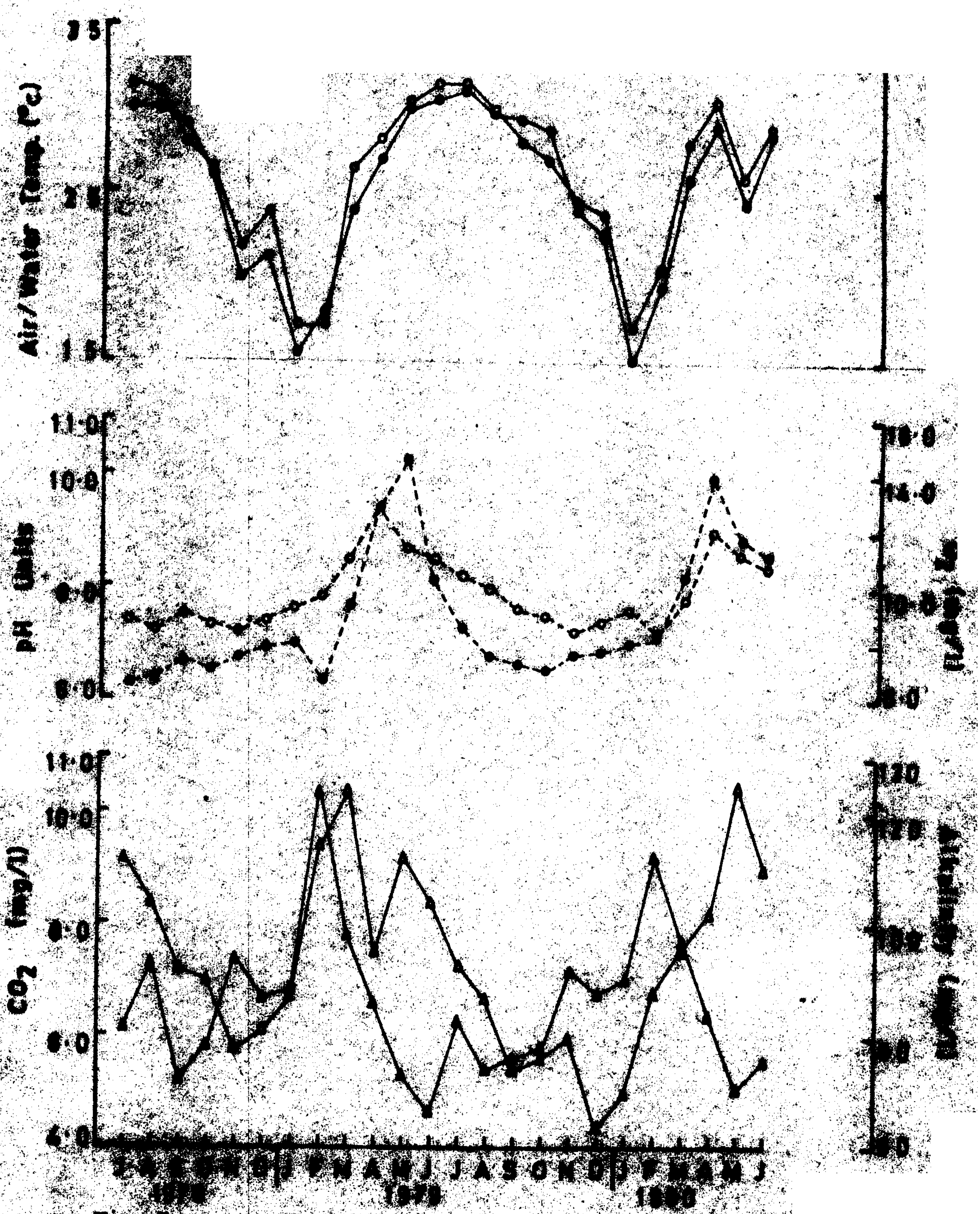


Fig. 5

2. Seasonal Abundance and Standing crop (biomass) :

The aquatic insects collected during the present investigation at the four fishponds namely Fish Dale Shillong, Mawpun, Kyrdemkulai and Ulubari belonged to five major orders. These were Hemiptera, Ephemeroptera, Odonata, Coleoptera and Diptera. In case of Hemiptera and Coleoptera both nymphs or larvae and adults were present in the samples. However, in the case of Odonata, Ephemeroptera and Diptera either nymphs or larvae were collected.

(i) Fish Dale, Shillong (Station 1) :

Studies on the seasonal abundance (numbers) and standing crop (biomass) of the five insect orders in Fish Dale Pond were carried out for a period of 18 months.

Hemiptera :

The mean density of Hemiptera showed marked fluctuations during the entire period of study (Figure 6-A). Their numbers decreased through June and July '78, which thereafter registered a sharp increase till a peak was obtained in September '78 with the highest of $77.2/m^2$. In the subsequent two months there was a decline, followed by a rise to attain a smaller peak in January '79. Once again a decrease in density was observed with the lowest of $22.9/m^2$ in May '79. The following summer witnessed another large peak in August '79 ($69.9/m^2$). A late summer and winter maxima and a spring minima was recorded for this order. The biomass however revealed a trend which differed from the density pattern of fluctuation (Figure 7-A). Although a distinct peak was indicated in September '78 ($1683.2\ mg/m^2$), the biomass was consistently high from October '78 to April '79. A second peak was indicated in August and September '79.

Hemiptera was represented by 4 families namely: Notonectidae, Corixidae, Nepidae and Gerridae.

Notonectidae was more numerous than the other three families. This was reflected in its seasonal abundance which indicated almost the same pattern as Hemiptera (Figure 8-A). The peak in September '78 was recorded with a value of $41.7/m^2$, followed by smaller one in January '79. Once again August '79 recorded another peak of abundance with $37.5/m^2$. The minimum value was recorded in June '79 ($8.8/m^2$). The biomass showed only a single large peak in January '79 ($576.1\ mg/m^2$) and relatively lower values during spring and summer months (Figure 9-A). This family was mostly represented by <u>Anisops</u> sp.

The Corixid population also showed almost a similar trend as of Notonectidae with slight variation (Figure 8-B). However, the overall magnitude of fluctuation was much lower than the latter. The density ranged between a minimum value of $6.2/m^2$ and a maximum of $21.9/m^2$. The peak value was recorded in August '78 as the maximum. July '79 recorded another increase with $19.8/m^2$. The lowest was recorded in April '78. The biomass record differed slightly from Notonectidae in that a large peak was in December '78 ($107.4\ mg/m^2$) and a small peak in July '79 ($44.3\ mg/m^2$) (Figure 9-B). This family was represented by <u>Agraptocorixa hyalinipennis</u> and <u>Micronecta</u> sp., with the former showing a winter maxima ($15.1/m^2$) and the latter a summer maxima ($16.7/m^2$) (Table-2).

The density of Nepidae remained very low throughout the period of study, with a minimum of $1.0/m^2$ recorded in January '79 and a maximum of $7.3/m^2$ in March '79 (Figure 8-C). Although this family represented the lowest density among the families of

Hemiptera, the biomass revealed highest values. However, the peaks of biomass and density were on different dates. The biomass showed a large peak in September '78 (1427.1 mg/m^2) with two slightly smaller ones in March '79 (1211.6 mg/m^2) and in August-September (967.2 mg/m^2, 941.7 mg/m^2) (Figure 9-C). This family comprised of two species: Ranatra filiformis and Laccotrephes grossus. As both the species were numerically small, they failed to show any distinct seasonality.

The Gerridae indicated fluctuations almost similar to Notonectidae, although the magnitude of fluctuation was lower than in the latter (Figure 8-D). The maximum was recorded in January '79 (21.8/m^2), while the minimum was in June '78 (1.7/m^2). September '78 (19.8/m^2) recorded another rise. A small rise was also indicated in August '79 (16.7/m^2). The standing crop data showed a totally different trend of fluctuation (Figure 9-D). The maximum increase was recorded only in August '79 (116.6 mg/m^2). No clear maxima was indicated during the period from April '78 to July '79, although the values showed minor fluctuations. The family was represented by Gerris adelaidis , Neogerris parvulus and Limnogonus nitidus. Among the three species, N. parvulus represented the maximum density (18.7/m^2) followed by G. adelaidis (15.6/m^2). The latter was present throughout the study period except in June '78 and November '78. While N. parvulus was absent during April '78 to August '78 and June to August '79, L. nitidus was not recorded during April to May '78, October '78 and January to June '79 (Table-2).

Ephemeroptera :

This group recorded the highest abundance among all the orders in this Station (Figure 6-B). However, their numbers remained negligibly low at the beginning of the study, indicating the minimum value of $2.1/m^2$ in June '78. Subsequently, the density increased rapidly from August '78 till the peak in December '78 with $191.7/m^2$. This abundance was followed by a sharp decline, and except for a slight increase in February '79, the density showed downward trend till May '79. After this, it started increasing gradually. The standing crop values however indicated slightly different trends and the peak was observed in September '78 (185.0 mg/m^2) (Figure 7-B). As for density however, the lower values of standing crop were noted from April to August in both the years.

Ephemeroptera was represented by only one family: Baetidae with a single representative : Cloeon sp.1.

Odonata :

The group Odonata indicated a trend of fluctuation which differed slightly from Hemiptera (Figure 6-C). The magnitude of fluctuation was also lower than in the latter. The density recorded small peaks in September '78 ($22.9/m^2$) and December '78 ($22.3/m^2$). However, the maximum density was observed in August '79 ($28.2/m^2$). The minimum value was seen in June '79 ($4.7/m^2$) of the second cycle. The biomass estimation showed a large peak in October '78 (1248.7 mg/m^2) and a small one in August '79 (699.9 mg/m^2) (Figure 7-C).

Odonata was represented by three families: Libellulidae, Aeshnidae and Coenagrionidae.

Libellulidae showed fluctuations similar to the group Odonata as a whole (Figure 10-B). The density ranged between a minimum value of $1.0/m^2$ and a maximum of $12.5/m^2$. Two peaks - one in September ($10.4/m^2$) and the other in December ($11.9/m^2$) were recorded in the first year. However, the maximum abundance was noted in August '79. As of Odonata, the peaks in standing crop did not reflect the density trend (Figure 11-B). The maximum value of biomass was recorded in October '78 (1121.5 mg/m^2). A smaller peak was however indicated in August-September '79 (413.3 mg/m^2 and 402.4 mg/m^2). This family was represented by <u>Orthetrum</u> sp.

The density of Aeshnidae remained negligibly low throughout the study period with a maximum of $4.2/m^2$ in August '79 (Figure 10-C). They were found to be absent from April to July '78 and April to June '79. The biomass of the family did not correspond to its low density, and had peak values in September '78 (143.9 mg/m^2) and August '79 (190.0 mg/m^2), the latter reflecting the maximum value (Figure 11-C). The family was represented by a single species : <u>Anax nigrofasciatus nigrolinatus</u>.

The abundance of Coenagrionidae indicated a trend almost similar to that of Libellulidae with two peaks in 1978, one in September ($9.4/m^2$) and the other in December ($10.4/m^2$) (Figure 10-D). The peak of increase in the second year was noted in August with the maximum of $11.5/m^2$. The minimum was in March '79. An autumn and winter maxima and a spring minima was observed for this family. However, the biomass data revealed much lower values than Libellulidae, the maximum being estimated at 220.1 mg/m^2 in November '78 (Figure 11-D). A second rise in biomass was indicated in August '79. The family was represented by a single unidentified species.

Coleoptera :

The trend of fluctuations of Coleopteran population differed from the other orders, although the magnitude of variation was almost similar to Odonata (Figure 6-D). Their density ranged from 7.3/m^2 to 27.0/m^2. From April to October '78, the density was generally high without any pronounced peak. The value reached its lowest in December '78, following which it rose and attained the peak in February. Thereafter, the density decreased except in June and July '79, and once again recorded the lowest in August '79. A spring maxima and winter and summer minima was indicated for this Order. Coleoptera recorded the highest standing crop values among all the orders (Figure 7-D). As of density, the peak of maximum biomass was seen in February '79 (2778.1 mg/m^2). A second pulse was however indicated in October '78 (2022.2 mg/m^2).

Coleoptera was represented by two families : Dytiscidae and Hydrophilidae.

Dytiscidae was more numerous of the two families, and followed a pattern of fluctuation almost similar to the order Coleoptera (Figure 12-A). The maximum density was observed in February '79 (25.0/m^2) while the minimum in August '79 (1.0/m^2). A small rise was also seen in August '78 (12.5/m^2). As in density, the biomass also revealed the same pattern as that of Coleoptera (Figure 13-A). A small pulse was seen in October '78, while the peak was noted in February '79 (2774.0 mg/m^2). This family was represented by the following species : Laccophilus sp., Hydaticus vittatus, Guignotus sp., Rhantus pulverosus and Cybister sp. Laccophilus showed the highest density (9.9/m^2) among the five species, followed by R. pulverosus (5.7/m^2) and Guignotus (4.7/m^2).

H. vittatus and *Cybister* were represented by very low numbers and their presence was restricted to a few months only (Table-2).

The trend of fluctuation of the family Hydrophilidae differed from that of the order Coleoptera (Figure 12-B). Its density recorded sharp increase from May '78 and attained a peak in abundance in June '78, with the maximum of $12.5/m^2$. The density declined subsequently and except for a slight increase in October '78, showed a downward trend till January '79, when the value reached the lowest of $1.0/m^2$. During the remaining months, the density indicated a small rise in April '79 and a large peak in July '79 ($10.4/m^2$). Thus, a summer maxima and winter minima was indicated for this family. Compared to Dytiscidae, Hydrophilidae exhibited negligibly low biomass (Figure 13-B). The trend of fluctuation was similar to its density with peak values in June '78 (19.6 mg/m^2) and July '79 (23.9 mg/m^2), the latter representing the maximum biomass. The family was represented by *Enochrus* sp. and *Helochares* sp. The density value of *Enochrus* ($9.4/m^2$) was higher than that for *Helochares* ($4.2/m^2$) (Table-2).

Diptera :

The abundance of Diptera fluctuated between a minimum value of $4.7/m^2$ and a maximum of $104.8/m^2$ (Figure 6-E). During 1978, it showed a small rise in September and a large peak in December, the latter being the maximum. However, the peak in the following year was in March ($82.3/m^2$). Lowest values ($4.8/m^2$, 4.7 m^2) were recorded in June in both the years. The biomass data indicated a small peak in December '78 (103.1 mg/m^2) with the peak of maximum increase in March '79 (188.6 mg/m^2) (Figure 7-E). This order included two families : Chironomidae and Culicidae.

'igure 6 : Showing the density of various orders of insects, in terms of numbers/m^2 at Station 1, over the study period.

A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera

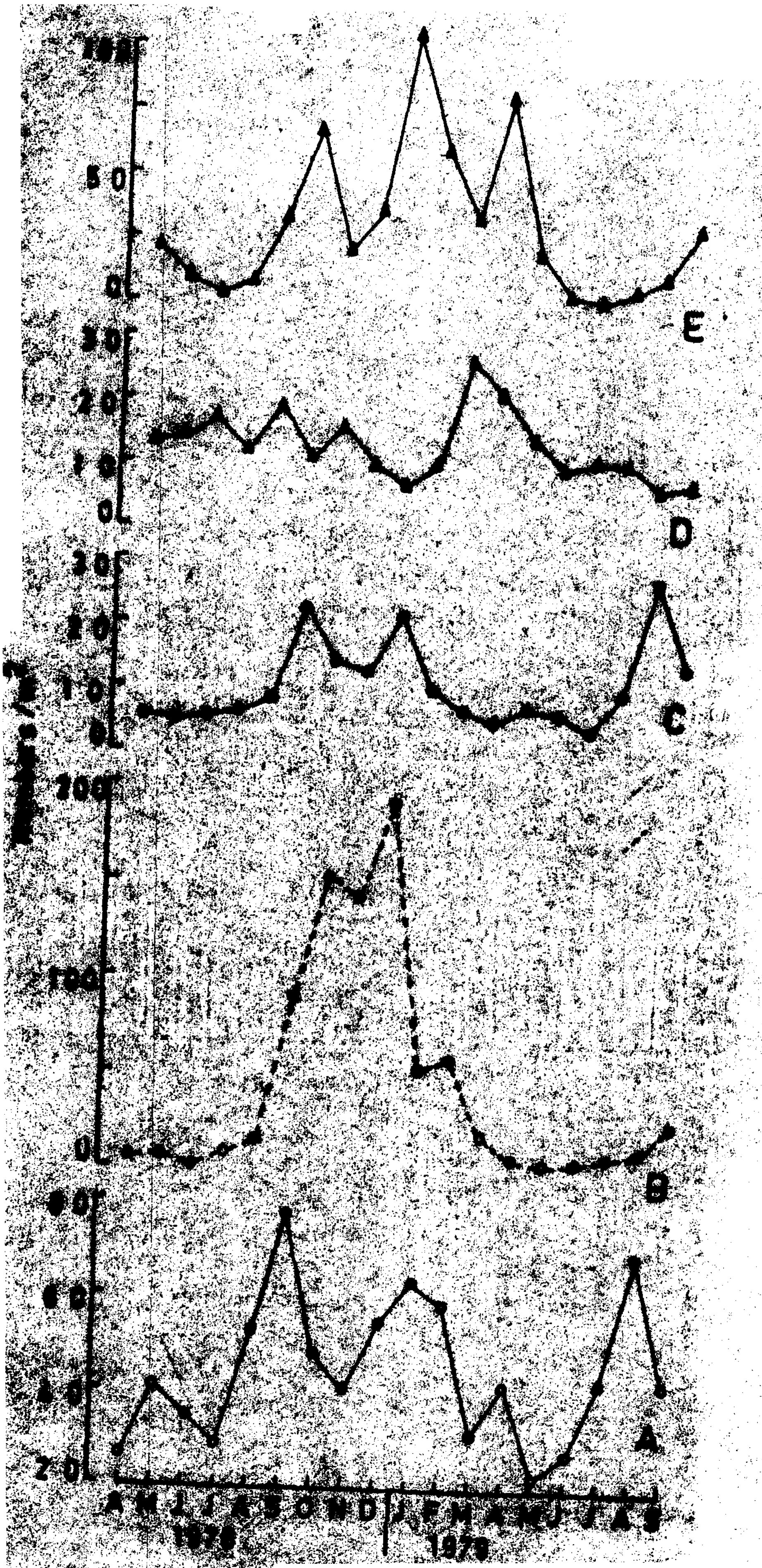


Fig 6

Figure 7 : Showing the biomass of various orders of insects, in terms of weight (mg)/m^2 at Station 1 over the study period.

A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera

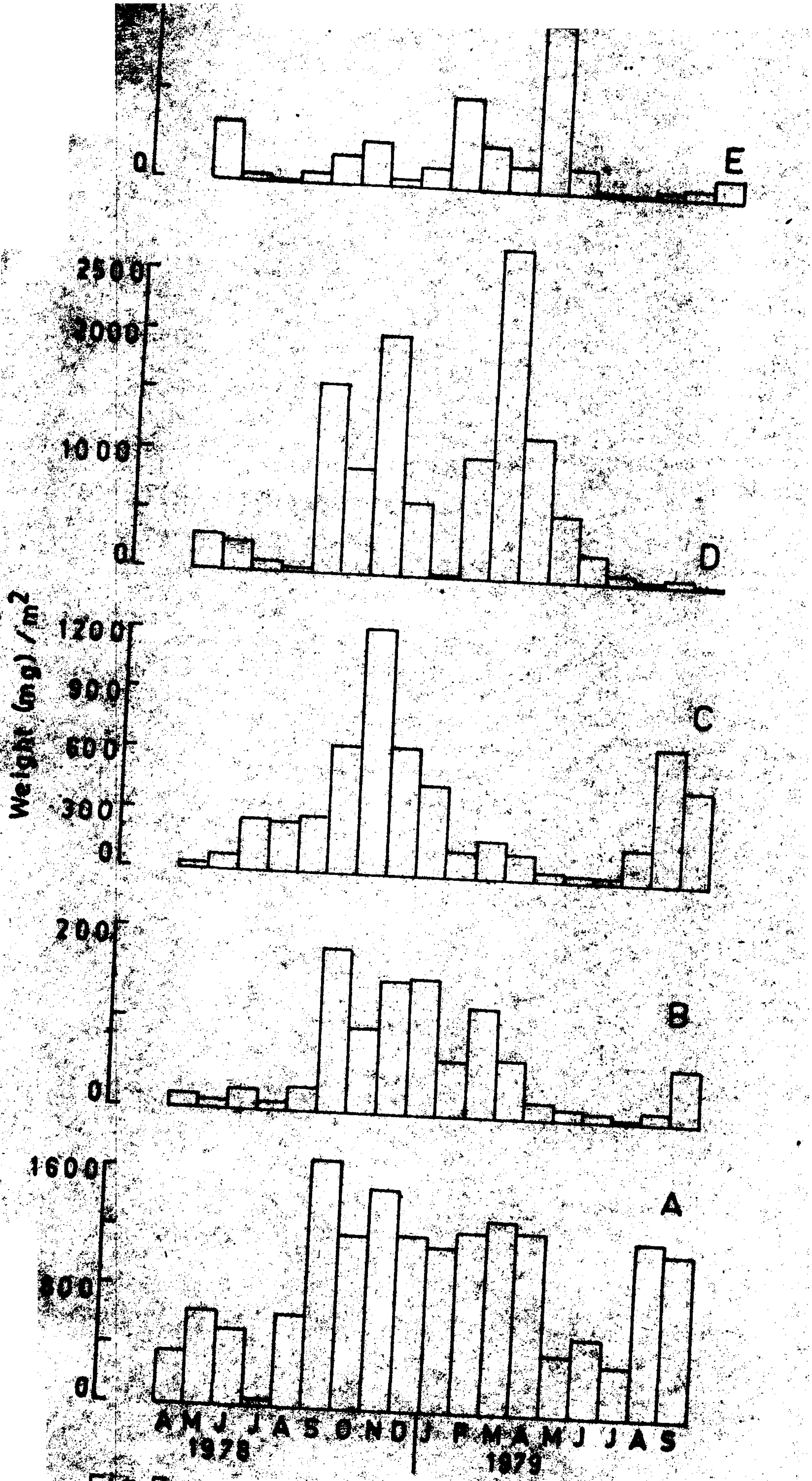

E
0
2500
2000
1000
0
D
Weight (mg) /m²
1200
900
600
300
0
C
200
0
B
1600
800
0
A
A M J J A S O N D J F M A M J J A S
1978
1979

Fig 7

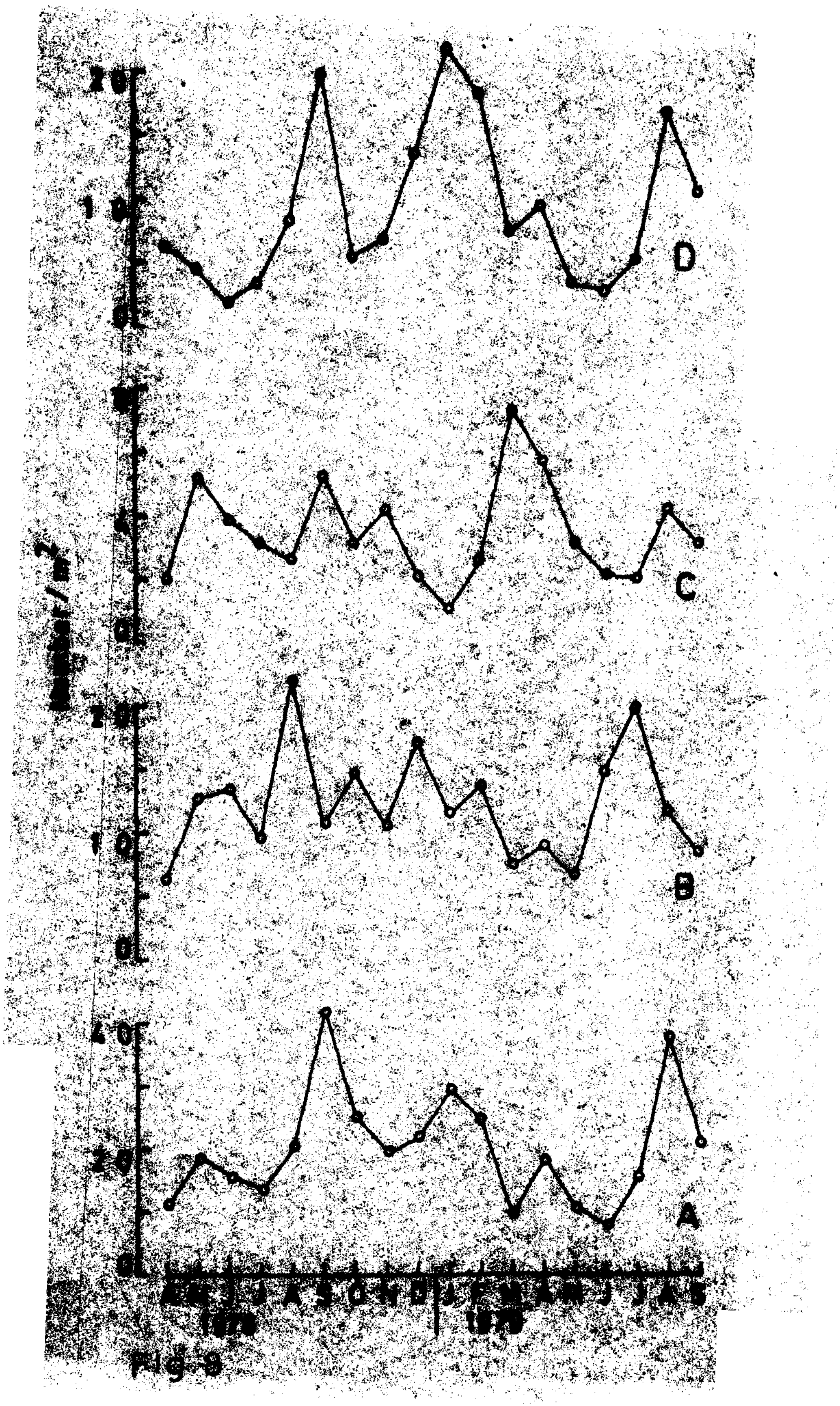


Fig 9

Figure 9 : Showing the biomass of various families of Hemiptera, in terms of weight (mg)/m^2 at Station 1, over the study period.

A - Notonectidae

B - Corixidae

C - Nepidae

D - Gerridae

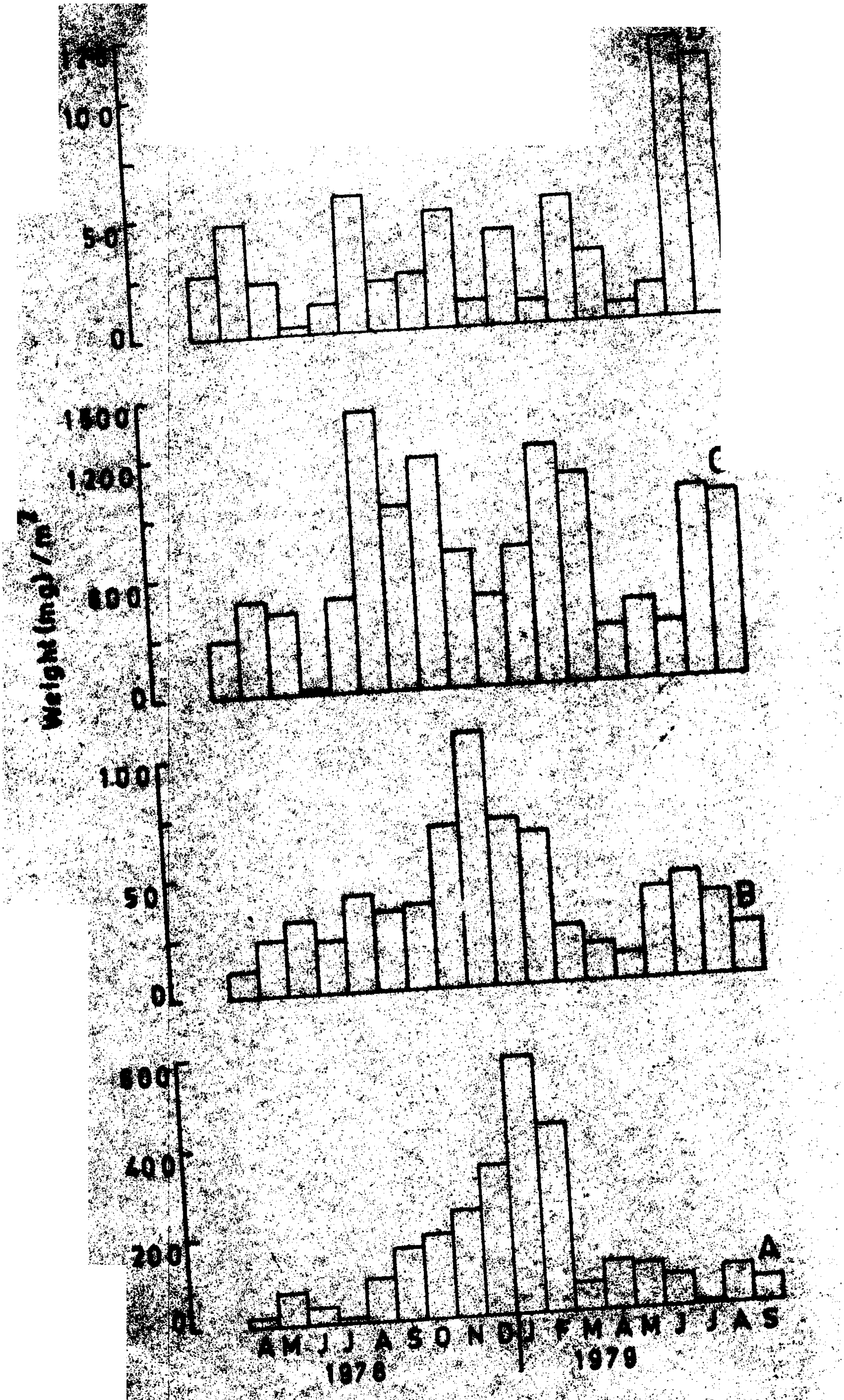

Weight (mg)/m²
D
100
50
0
C
1,500
1,200
600
0
B
100
50
0
A
600
400
200
0
A M J J A S O N D J F M A M J J A S
1978
1979

Fig. 9

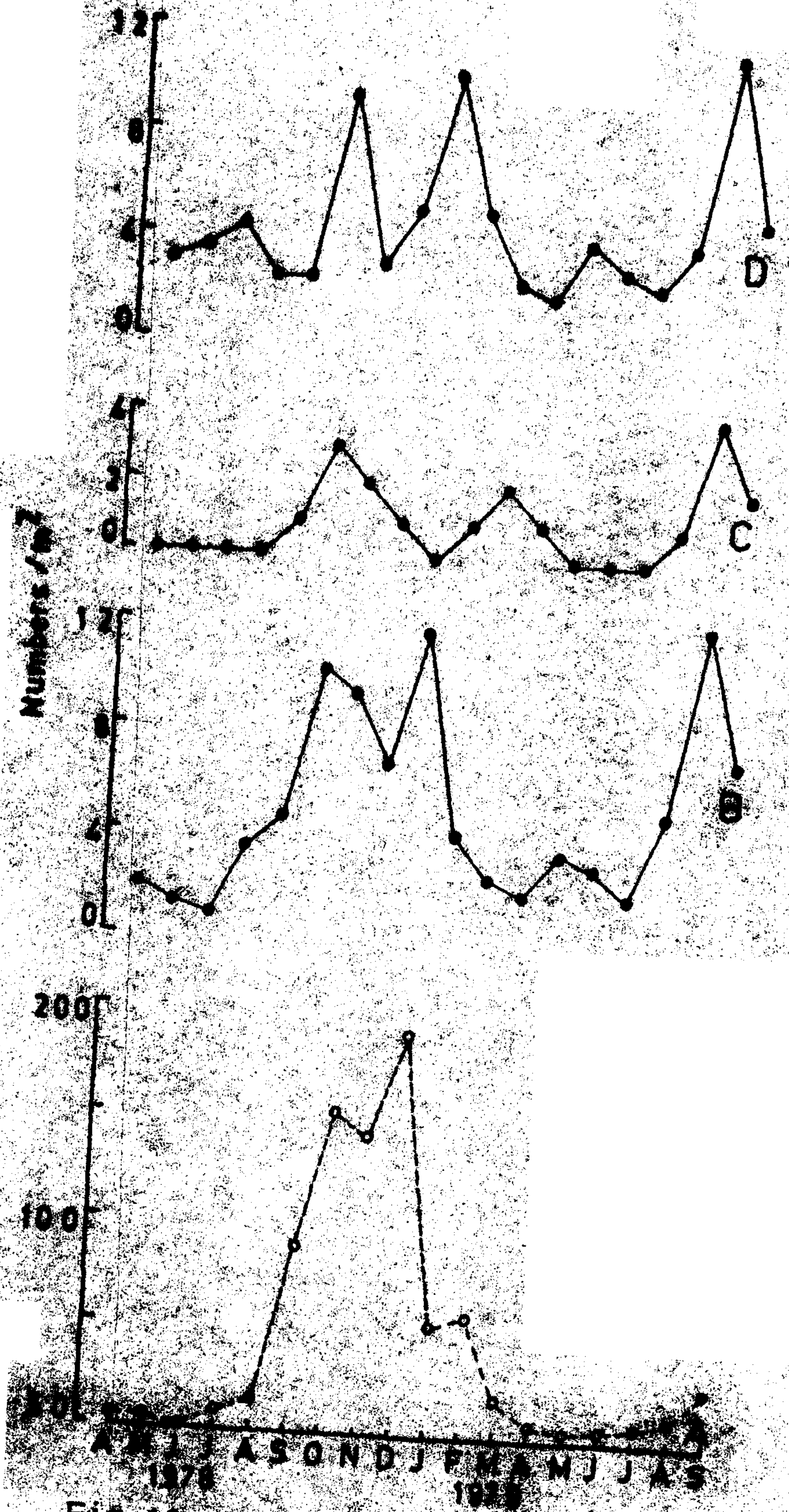


Fig. 10

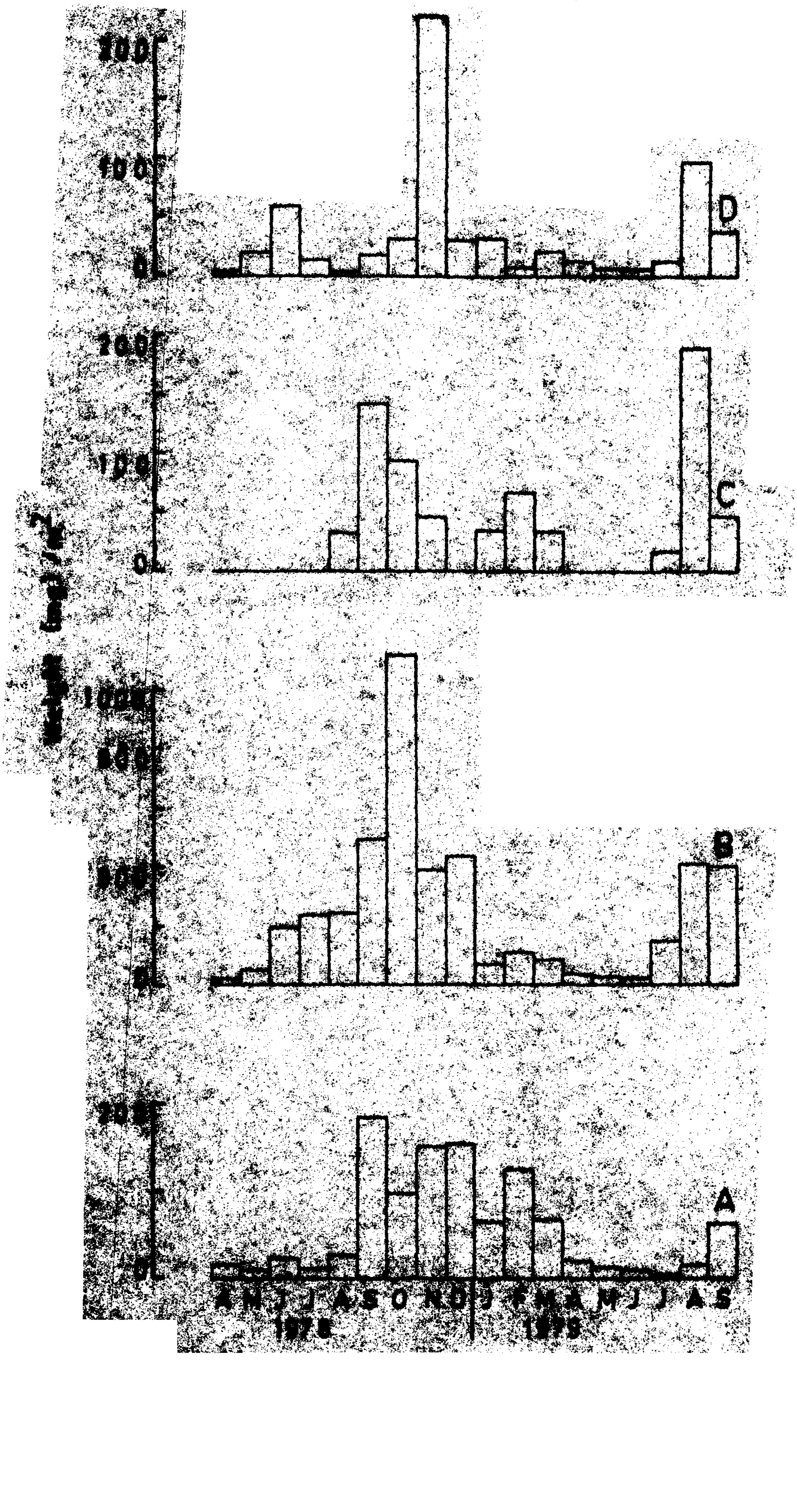
Figure 11 : Showing the biomass of various families of Ephemeroptera and Odonata in terms of weight (mg)/m^2 at Station 1 over the stydy period.

A - Baetidae

B - Libellulidae

C - Aeshnidae

D - Coenagrionidae



D
C
B
A
A M J J A S O N D J F M A M J J A S

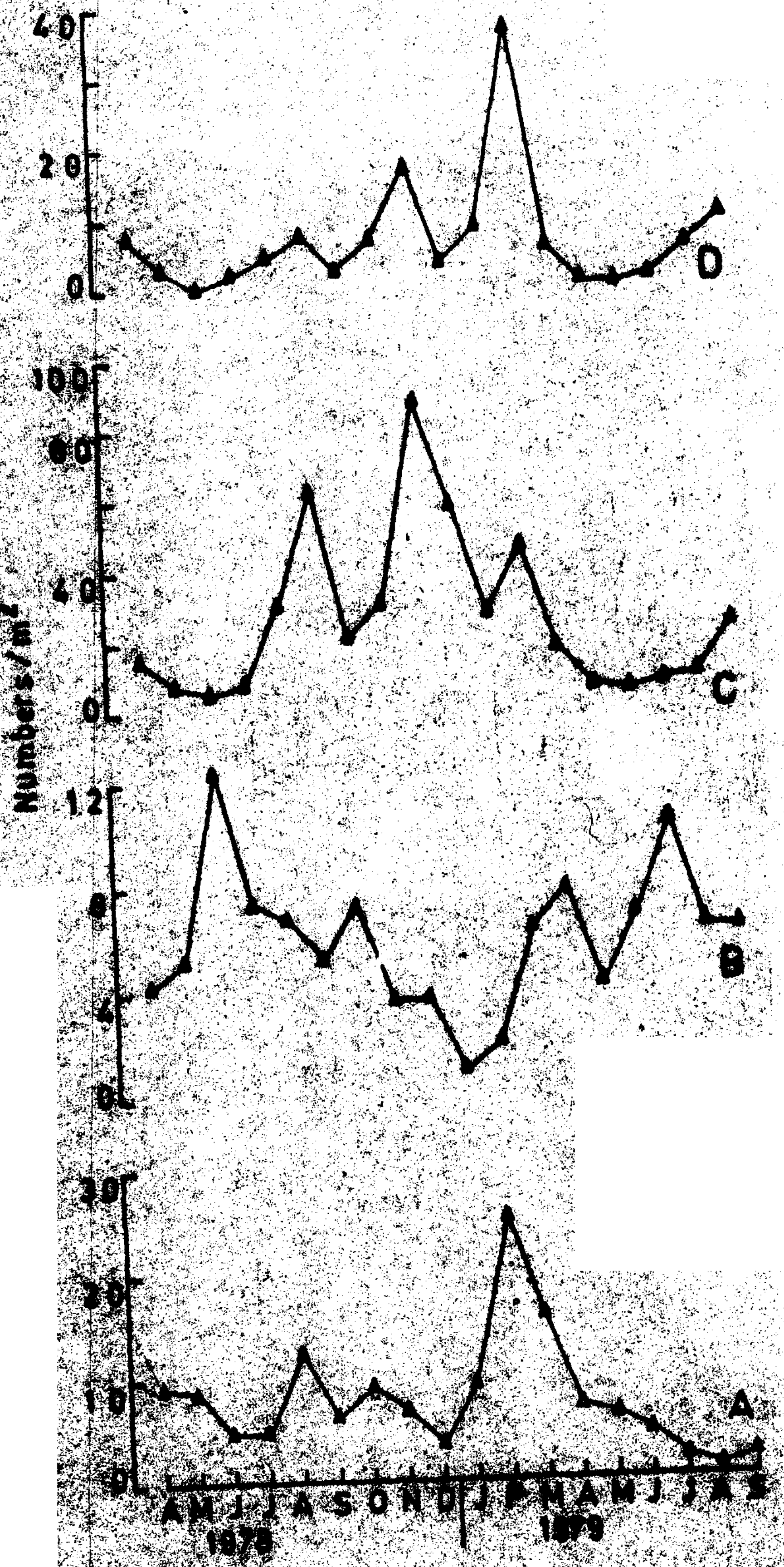
Figure 12 : Showing the density of various families of Coleoptera and Diptera in terms of numbers/m^2 at Station 1 over the study period.

A - Dytiscidae

B - Hydrophilidae

C - Chironomidae

D - Culicidae



40
20
0
D
100
80
40
0
C
12
8
4
0
B
30
20
10
0
A
Numbers/m²
A M J J A S O N D J F M A M J J A S
1978
1979

Fig 12

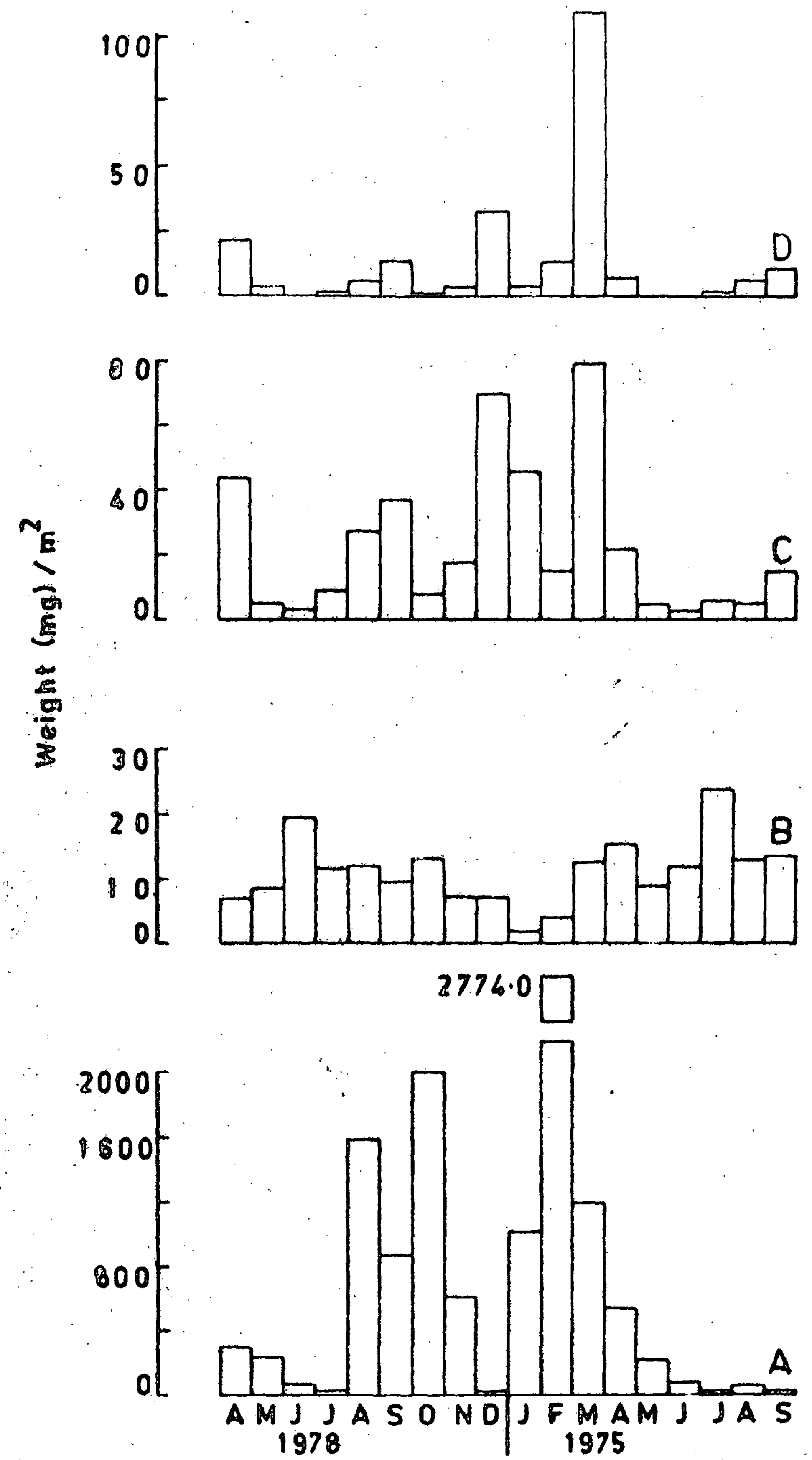
Figure 13 : Showing the biomass of various families of Coleoptera and Diptera in terms of weight (mg)/m^2 at Station 1 over the study period.

A - Dytiscidae

B - Hydrophilidae

C - Chironomidae

D - Culicidae



Weight (mg) / m^2
100
50
0
D
80
40
0
C
30
20
10
0
B
2774·0
2000
1600
800
0
A
A M J J A S O N D J F M A M J J A S
1978
1975

Fig. 13

TABLE-2 : Showing the density (no./m^2) of various species of insects at Station 1 over the study period.

Insect species

1. Anisops sp.
2. Agraptocorixa hyalinipennis Fabr.
3. Micronecta sp.
4. Ranatra filiformis Fabr.
5. Laccotrephes grossus Fabr.
6. Gerris adelaidis Dohrn.
7. Neogerris parvulus Stal.
8. Limnogonus nitidus Mayr.
9. Cloeon sp. 1
10. Orthetrum sp.
11. Anax nigrofasciatus nigrolinatus Fraser.
12. Unidentified Coenagrionidae
13. Laccophilus sp.
14. Hydraticus vittatus (Fab.)
15. Guignotus sp.
16. Rhantus pulverosus Stephens
17. Cybister sp.
18. Enochrus sp.
19. Helochares sp.
20. Anatopynia sp.
21. Brillia sp.
22. Unidentified Culicidae

TABLE-2

Insect species	1978									1979								
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1.	11.5	18.8	15.9	13.5	20.3	41.7	25.0	19.2	21.9	29.2	24.5	9.4	18.2	10.4	7.8	15.6	37.5	20.8
2.	3.1	6.6	2.7	2.1	5.2	4.2	7.3	5.7	15.1	6.3	9.9	3.1	2.1	2.1	5.7	7.3	4.2	3.1
3.	3.1	6.0	10.7	7.3	16.7	6.3	7.3	4.7	2.1	5.2	3.6	4.2	6.8	4.2	8.9	12.5	7.3	5.2
4.	1.0	3.6	2.4	2.1	1.6	2.1	1.0	1.6	0.5	-	1.0	4.2	3.1	2.1	0.5	1.0	2.1	1.0
5.	1.0	1.6	1.4	1.0	1.0	3.1	2.1	2.6	1.6	1.0	1.6	3.1	2.6	1.0	1.6	1.0	2.1	2.1
6.	6.3	4.5	-	1.0	3.1	15.6	4.2	-	1.0	3.1	7.8	4.2	3.1	2.1	2.6	4.2	11.5	6.3
7.	-	-	-	-	-	2.1	1.0	5.7	11.5	18.7	10.4	3.1	6.3	1.0	-	-	-	1.0
8.	-	-	1.7	2.1	5.2	2.1	-	1.0	1.0	-	-	-	-	-	-	1.0	4.2	3.1
9.	5.2	6.3	2.1	9.4	15.6	89.6	153.1	141.7	191.7	53.1	58.3	18.8	7.3	4.2	5.7	8.3	11.5	27.1
10.	2.1	1.4	1.0	3.6	4.7	10.4	9.4	6.8	11.9	4.2	2.6	2.1	3.6	3.1	2.1	5.2	12.5	7.3
11.	-	-	-	-	1.0	3.1	2.1	1.0	-	1.0	2.1	1.0	-	-	-	1.0	4.2	2.1
12.	3.1	3.6	4.5	2.6	2.6	9.4	3.1	5.2	10.4	5.2	2.6	2.1	4.2	3.1	2.6	4.2	11.5	5.2
13.	3.1	3.6	3.1	4.2	7.8	3.1	1.0	1.6	2.6	3.1	9.9	4.2	1.6	3.1	1.6	1.0	-	1.0
14.	1.0	0.5	-	-	-	-	1.0	0.5	-	1.0	2.6	1.0	0.5	-	-	-	-	-
15.	4.2	2.6	1.0	0.5	1.0	-	1.0	1.6	1.0	2.1	4.7	6.3	3.6	1.0	2.6	1.0	-	1.0
16.	1.0	2.1	0.6	-	1.6	2.1	4.2	2.6	-	2.1	5.7	3.1	1.0	2.1	0.5	-	1.0	-
17.	-	-	-	-	2.1	1.0	2.1	0.5	-	1.0	2.1	1.0	0.5	-	-	-	-	-
18.	2.1	3.6	8.3	5.2	6.3	4.2	5.2	2.6	2.1	1.0	1.0	4.2	5.2	3.1	5.2	9.4	4.2	5.2
19.	2.1	1.6	4.2	2.1	0.5	1.0	2.1	1.0	1.6	-	1.0	2.1	2.6	1.0	1.6	1.0	2.1	1.0
20.	3.1	-	-	4.2	20.3	13.5	5.2	23.9	76.6	51.0	14.6	3.1	6.8	3.1	2.1	-	5.2	8.3
21.	11.5	7.3	4.8	3.1	9.9	48.9	14.6	6.3	11.5	7.3	12.5	42.7	10.4	3.1	2.6	7.3	4.2	15.6
22.	7.3	2.6	-	1.6	4.2	7.3	2.1	6.8	16.7	3.1	8.3	36.5	5.2	-	-	1.0	5.2	9.4

Of these, Chironomidae was more numerous and its density indicated a trend of fluctuation similar to Diptera (Figure 12-C). A small pulse in September and a large peak as the maximum value in December (88.1/m^2) was observed in 1978. Minimum values (4.8/m^2 and 4.7/m^2) were recorded in June in both the years. The biomass however indicated its maximum in April '78 (43.9 mg/m^2), December '78 (70.0 mg/m^2) and March '79 (79.1 mg/m^2), the latter representing the peak (Figure 13-C). The family included : Anatopynia sp. and Brillia sp. The maximum density value of Anatopynia (76.6/m^2) was higher than that for Brillia (48.9/m^2). While the former recorded its maximum in December '78 the latter showed the same in September '78 (Table-2).

Besides indicating low magnitude, the pattern of fluctuations of Culicidae differed from that of Chironomidae (Figure 12-D). The density revealed a small rise in December '78 and a peak in March '79 (36.5/m^2). No specimen was collected in June '78 and May, June '79. The biomass values indicated the same trend as of density, with the peak in March '79 (109.5 mg/m^2) (Figure 13-D). The family was represented by larval stages which were not identified.

(ii) Mawpun Fish Pond (Station 2) :

The seasonal abundance (numbers) and standing crop (biomass) of the five insect orders in Mawpun Fish Pond was recorded for a period of two annual cycles.

Hemiptera :

The fluctuations of Hemipteran populations differed slightly from Station 1, indicating only a late summer maxima and spring minima (Figure 14-A). During the first annual cycle (1978-79), the density showed a sharp increase from July '78 and reached its peak in September '78 ($77.0/m^2$), followed by steady decline. The downward trend continued till it reached the minimum in April '79 ($4.2/m^2$) after which it rose again. The trend of fluctuations in the second cycle was similar to that of the first indicating a peak in October '79 with $81.3/m^2$, which also represented the highest density among all the orders in this station. The minimum value was noted in March '80 during the second cycle. The standing crop estimation indicated almost similar fluctuations with peak values (928.0 mg/m^2, 832.2 mg/m^2) recorded in October in both the cycles (Figure 15-A).

Hemiptera comprised of five families : Notonectidae, Corixidae, Nepidae, Gerridae and Belostomatidae.

Notonectidae, being the most abundant among the families of Hemiptera, showed pattern of fluctuations similar to that of the entire order (Figure 16-A). A peak of increase was recorded in September '78 ($56.2/m^2$) and October '79 ($61.5/m^2$) of the first and second annual cycles respectively. The minimum value was noted in April '79 ($2.1/m^2$) of the former and March '80 ($2.1/m^2$) of the latter. The biomass data revealed the same trend with peak values in October (674.1 mg/m^2 and 781.8 mg/m^2) in both the years (Figure 17-A). The family was represented by a single species : Anisops batilliforns.

The density fluctuations of the family Corixidae differed from station 1 (Figure 16-B). The first annual cycle recorded a large peak in December '78 ($26.0/m^2$) representing the maximum density, while nil values were observed in April and May '79.

The second annual cycle had its peak in July '79 ($17.7/m^2$) and November '79 ($19.8/m^2$). Nil value was again recorded in the month of April during this cycle. The standing crop however indicated only summer peaks : a small pulse in August '78 (86.0 mg/m^2) of the first annual cycle and a large peak in July '79 (143.4 mg/m^2) of the second annual cycle (Figure 17-B). This family was represented by two species : Agraptocorixa hyalinipennis and Micronecta sp. The maximum density of Micronecta ($22.9/m^2$) was slightly higher than that of A. hyalinipennis ($16.7/m^2$). The former showed winter maxima, while the latter recorded summer maxima. Nil values were recorded for A. hyalinipennis during March to May of the first annual cycle and February to April of the second. Micronecta totally disappeared during April, May, July and August, of the first and April of the second annual cycle (Table-3).

Compared to other families, the density of Nepidae was very low with the maximum of $3.1/m^2$ in October '78 (Figure 16-C). No specimens were collected during February to April, and in July of the first and September to October and December to May of the second annual cycle. The biomass values indicated a large peak in October '78 (201.7 mg/m^2) and a smaller pulse in July-August '79 (98.4 mg/m^2 and 97.1 mg/m^2) (Figure 17-C). The family included a single species : Ranatra filiformis.

The pattern of fluctuations of Gerridae differed from the Station 1, indicating a late autumn maxima and a summer and spring minima (Figure 16-D). The maximum values were recorded in November ($10.4/m^2$ and $8.3/m^2$) in both cycles. The family was totally absent during June of the first annual cycle and March to May of the second. The biomass record revealed the same trend except that the November peak (35.6 mg/m^2) of the first year was shifted to December (24.2 mg/m^2) in the second year (Figure 17-D). The family included two species : Neogerris parvulus and Limnogonus nitidus. L. nitidus was present only for a period of three months (August '78 to October '78) during the entire investigation.

Beside revealing low densities, the family Belostomatidae had an irregular seasonal fluctuation (Figure 16-E). Further it occurred only during July to October '78 and June to December '79. The maximum density of 7.3/m^2 was recorded in September '79. It showed the lowest biomass among the families of Hemiptera (Figure 17-E). Peak values in biomass was observed in September-October '79 (6.3 mg/m^2 and 6.6 mg/m^2). This family was represented by Diplonychus rusticus.

Ephemeroptera :

The abundance of Ephemeroptera showed similarity with the trend in Station 1, in having peak values during the winter months (Figure 14-B). However, the magnitude of fluctuations was much lower in the present case. The maximum value was observed in February (30.2/m^2) during the first cycle while the same was noted in January (27.1/m^2) during the second cycle. Minimum was recorded in May (3.1/m^2) and March (3.1/m^2) of the first and second cycle respectively. The biomass indicated the same fluctuations with peaks in February '79 (63.5 mg/m^2) and January '80 (65.0 mg/m^2) (Figure 15-B).

Ephemeroptera comprised of two families : Baetidae and Caenidae.

Baetidae was more abundant of the two families, and showed fluctuational trends of the order Ephemeroptera, with peak values in February '79 (29.2/m^2) and January '80 (25.0/m^2) (Figure 18-A). The biomass also indicated the same trend with peaks observed in February '79 (61.8 mg/m^2) and January '80 (62.6 mg/m^2) (Figure 19-A). The family was represented by <u>Cloeon</u> sp.1.

Caenidae showed very low density and irregular seasonal fluctuations (Figure 18-B). The peak density was in January '79 (5.2/m^2) and November '79 (7.3/m^2) of the first and second cycle respectively. Standing crop values also had their maxima in January '79 (6.9 mg/m^2) and November '79 (9.7 mg/m^2) (Figure 19-B). The family was represented by <u>Caenis</u> sp.

<u>Odonata</u> :

The Odonata revealed a late summer maxima and spring minima for this Station (Figure 14-C). It recorded the maxima in September (16.7/m^2 and 25.5/m^2) during both the first and second annual cycles, although the value in the latter year is seen to be higher than that of the former. The minimum values were observed in May (0.0/m^2) of the first and April (1.0/m^2) of the second cycle. The biomass record however, indicated its peak values in July '78 (179.9 mg/m^2) and September '79 (182.1 mg/m^2) of the first and second cycle respectively (Figure 15-C).

Odonata was represented by three families : Libellulidae, Lestidae and Coenagrionidae.

Libellulidae indicated the same pattern of fluctuations as Odonata except that there was a slight shift in the peak of the first annual cycle (Figure 18-C). It reached the maximum in November '78 (7.3/m^2) of the first and September '79 (9.9/m^2) of the second annual cycle. The family was not recorded during February, March, May '79 and also from January to April '80. Standing crop estimation followed the same trend as that of density, with a small pulse in November '78 (38.8 mg/m^2) and the peak in September '79 (80.8 mg/m^2) (Figure 19-C). Tramea similata was the only species representing this family.

The next family Lestidae had an irregular seasonal fluctuation, recording nil values during November '78 to May '79 and January to May '80 (Figure 18-D). The maximum value was seen in July '78 (5.2/m^2) and September '79 (7.8/m^2) of the first and second annual cycle respectively. The biomass however indicated the maximum in July '78 (166.1 mg/m^2) (Figure 19-D). The family was represented by Lestes sp.

The last family Coenagrionidae indicated a trend of bimodality with highest values recorded in September (9.4/m^2) and December (7.3/m^2) of the first cycle and September (7.8/m^2) and February (8.3/m^2) of the second cycle (Figure 18-E). Nil values were reported during April to June '79 and in May '80. Biomass fluctuations recorded its peak only in September '78 (44.3 mg/m^2) of the first cycle, while it was both in September '79 (30.4 mg/m^2) and February '80 (44.6 mg/m^2) of the second cycle (Figure 19-E) The family was represented by an unidentified species.

Coleoptera :

The monthly abundance of Coleoptera revealed a steady increase from July '78 in the first year, reaching a peak in September '78 (12.5/m^2) (Figure 14-D). Subsequently, the populati showed a gradual decline till the disappearance in February '79. It reappeared in the very next month (March '79) and again indicated steady increase until the highest was attained in June '79 (15.6/m^2). In the remaining months, the density recorded a downward trend with intervening periods of minor increases. A summer or a late summer maxima was recorded for this order. Though numerically the smallest, Coleoptera represented the highest biomass among all the orders, as in Station 1 (Figure 15-D). Fluctuations of the biomass noted almost the same pattern as density with peak values in October '78 (851.9 mg/m^2) and June '79 (1420.2 mg/m^2), the latter representing the highest.

Coleoptera comprised of three families : Dytiscidae, Hydrophilidae and Gyrinidae.

Dytiscidae recorded the highest density among the three families (Figure 20-A). It indicated almost the same pattern as of Coleoptera, with the peak in June (13.0/m^2) during the first annual cycle. The family was not recorded from January to February '79 and October '79 to February '80. Biomass record also revealed the peak in June '79 (1408.0 mg/m^2) (Figure 21-A). The family included Laccophilus sp., Guignotus sp., Cybister sp. and Rhantus pulverosus. All the species recorded low density and their occurrence was limited to a few months in both the annual cycles. Laccophilus sp. showed the maximum density (5.7/m^2), followed by Guignotus sp. (5.2/m^2). Maximum values were seen during autumn or summer months (Table-3).

The density of Hydrophilidae fluctuated between nil and 6.3/m^2 (Figure 20-B). The first annual cycle recorded a peak in September '78 (6.2/m^2) while the second cycle reached the maximum in August '79 ($6.3/m^2$). No specimens were obtained during February to May '79 and March to June '80. A late summer maxima and spring minima in both the cycles was recorded for this family. Biomass estimation indicated the same trend as of density with peaks in September '78 (38.8 mg/m^2) and August '79 (42.5 mg/m^2) (Figure 21-B). The family was listed by Berosus pulchellus and Enochrus sp. While B. pulchellus was present during July to October '78 and June to October '79, Enochrus was seen during September '78 to January '79 and again from November '79 to February '80.

The last family Gyrinidae occurred in very low densities, ranging between nil and $4.2/m^2$ (Figure 20-C). Its presence was restricted to a few months in both the annual cycles. The maximum value was recorded in September '78. It recorded nil values during December '78 to February '79 and November '79 to April '80. The standing crop also recorded the maximum value in September '78 (43.5 mg/m^2) and a minor pulse in May '79 (35.9 mg/m^2) (Figure 21-C). The family included two species : Dineutus unidentatus and Gyrinus smaragdinus.

Diptera :

With density values ranging between $2.1/m^2$ to $30.2/m^2$, the order Diptera revealed large fluctuations (Figure 14-E). The first cycle recorded the maximum abundance in February '79 ($27.1/m^2$) and June '79 ($30.2/m^2$), while the second cycle recorded the same only in February '80 ($20.9/m^2$). The former indicated the minimum value in October '78 ($3.1/m^2$) while the latter indicated the same in October '79 ($2.1/m^2$) and June '80 ($2.1/m^2$). However, the standing crop reached the highest in March '79 (42.0 mg/m^2)

Figure 14 : Showing the density of various orders of insects in terms of numbers/m^2 at Station 2 over the study period.

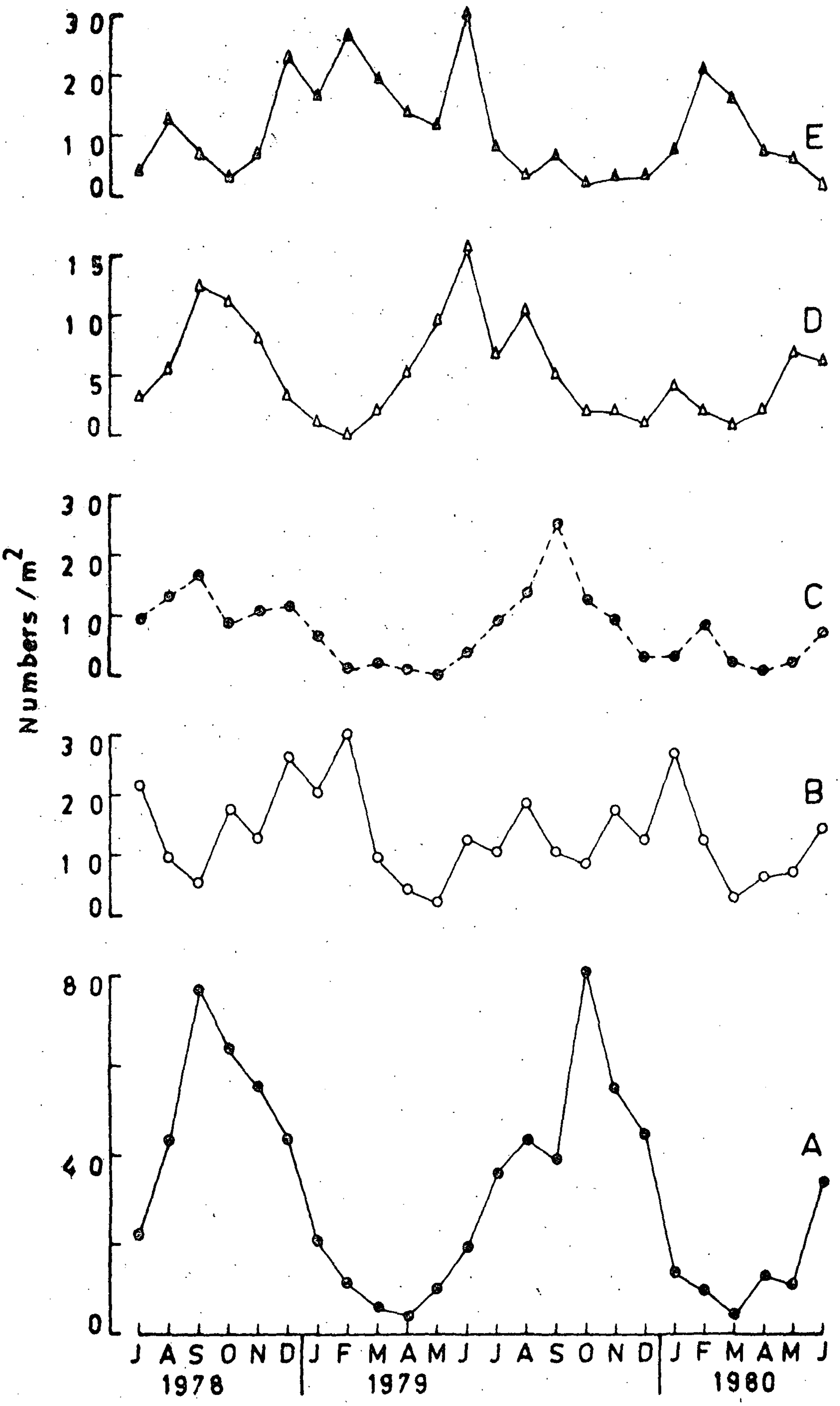
A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera



Numbers /m²
E
D
C
B
A
30
20
10
0
15
10
5
0
30
20
10
0
30
20
10
0
80
40
0
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig.14

Figure 15 : Showing the biomass of various orders of insects in terms of weight (mg)/m^2 at Station 2 over the study period.

A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera

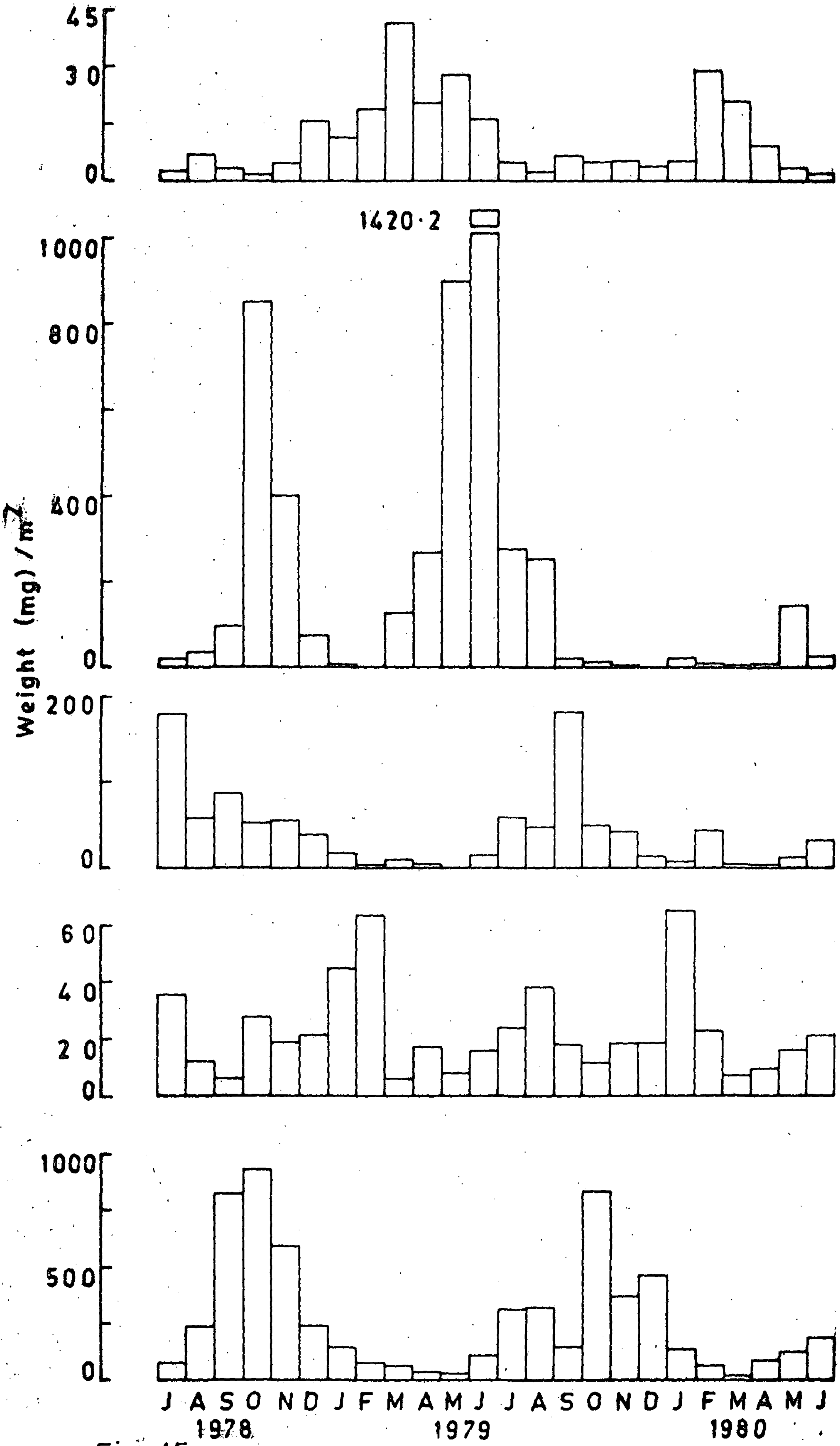

45
30
0
1420·2
1000
800
400
0
Weight (mg) / m²
200
0
60
40
20
0
1000
500
0
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 15

Figure 16 : Showing the density of various families of Hemiptera in terms of numbers/m^2 at Station 2 over the study period.

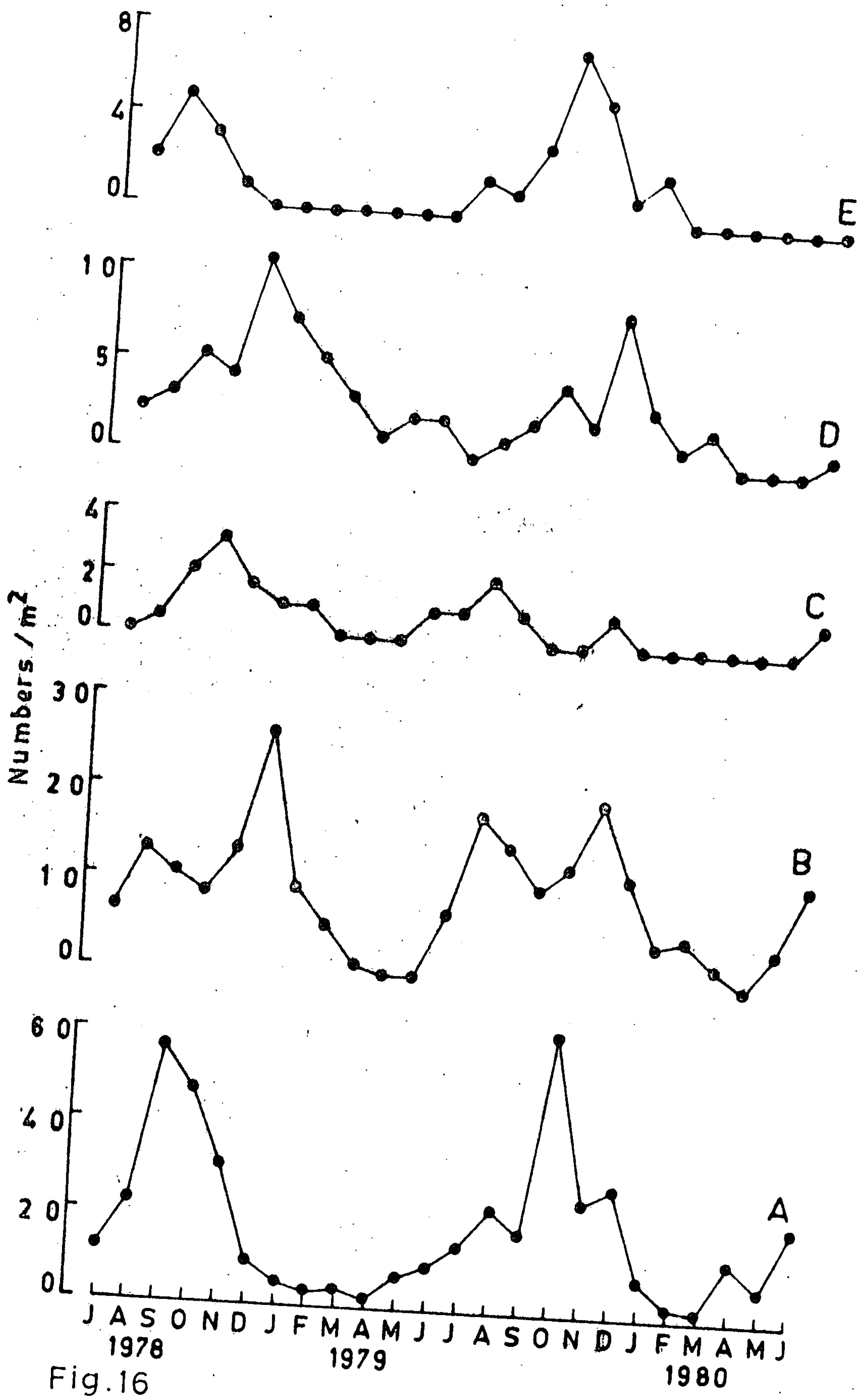
A - Notonectidae

B - Corixidae

C - Nepidae

D - Gerridae

E - Belostomatidae



Numbers / m²
8
4
0
E
10
5
0
D
4
2
0
C
30
20
10
0
B
60
40
20
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig.16

Figure 17 : Showing the biomass of various families of Hemiptera in terms of weight (mg)/m^2 at Station 2 over the study period.

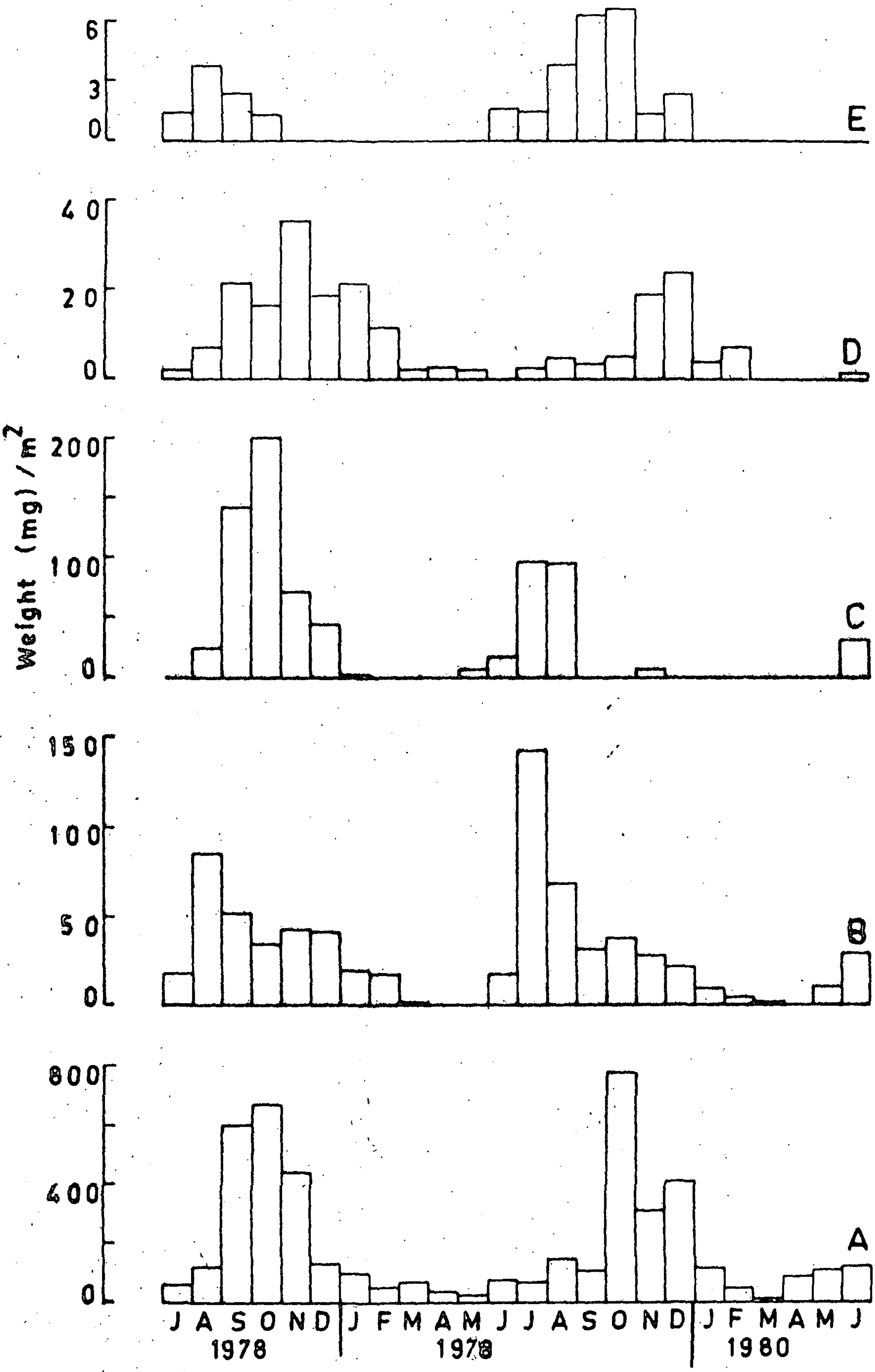
A - Notonectidae

B - Corixidae

C - Nepidae

D - Gerridae

E - Belostomatidae



6
3
0
E
4 0
2 0
0
D
200
100
0
C
Weight (mg) / m2
150
100
50
0
B
800
400
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1978
1980

Fig. 17

Figure 18 : Showing the density of various families of Ephemeroptera and Odonata in terms of number/m^2 at Station 2 over the study period.

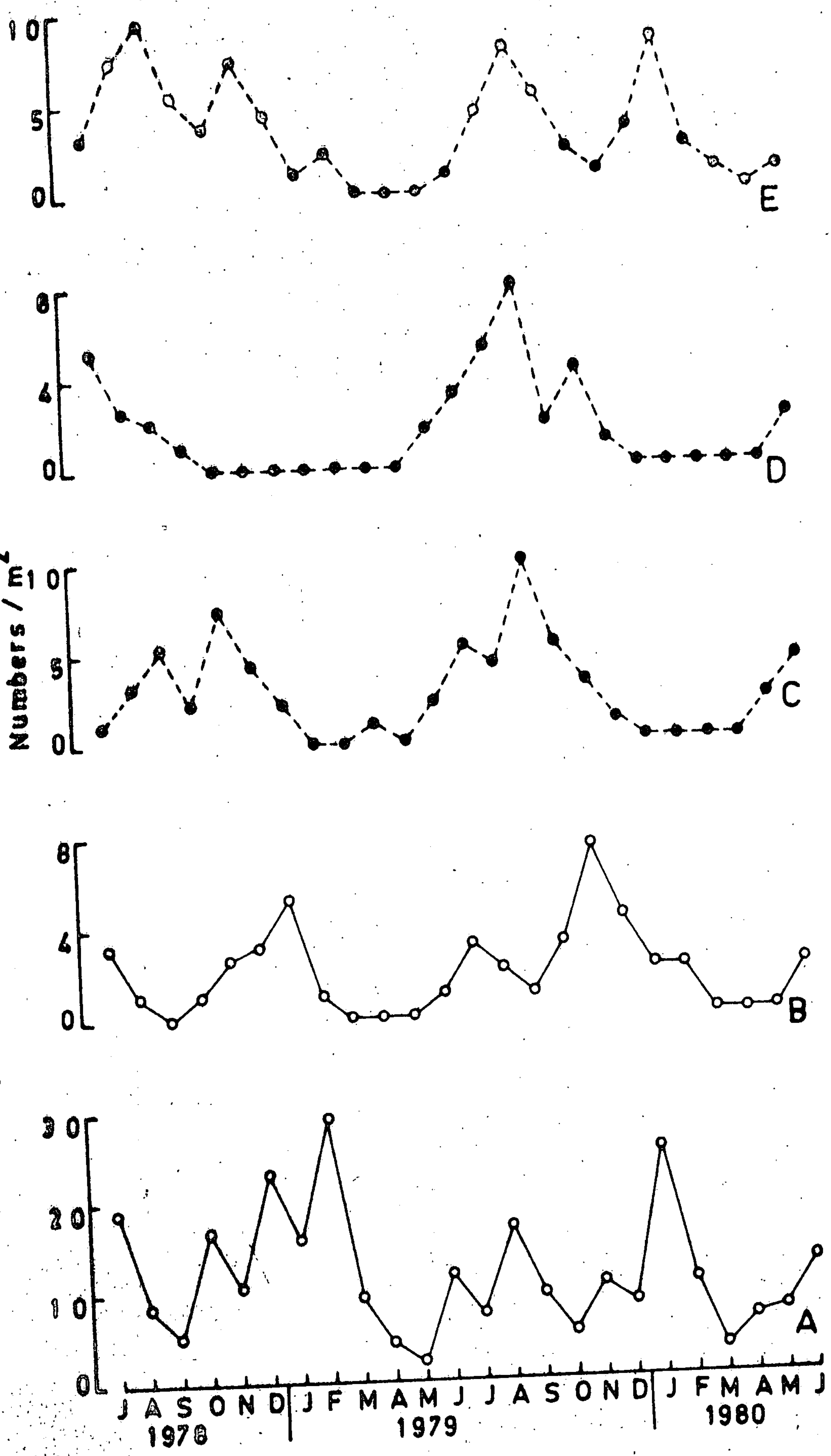
A - Baetidae

B - Caenidae

C - Libellulidae

D - Lestidae

E - Coenagrionidae



Numbers / m2
10
5
0
E
8
4
0
D
10
5
0
C
8
4
0
B
30
20
10
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig.18

Figure 19 : Showing the biomass of various families of Ephemeroptera and Odonata in terms of weight (mg)/m^2 at Station 2 over the study period.

A - Baetidae

B - Caenidae

C - Libellulidae

D - Lestidae

E - Coenagrionidae

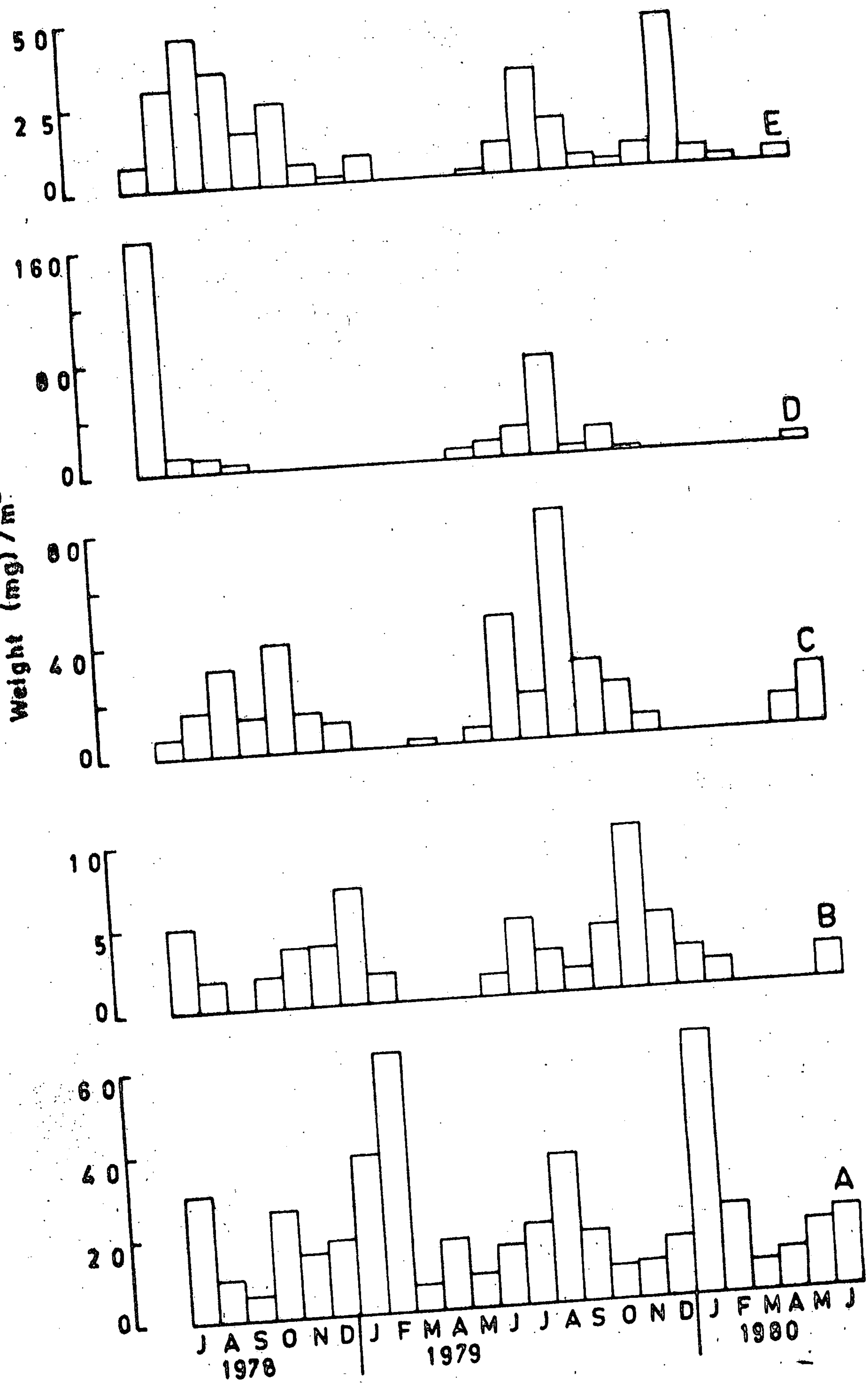

Weight (mg)/m²
50
25
0
E
160
80
0
D
80
40
0
C
10
5
0
B
60
40
20
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 19

Figure 20 : Showing the density of various families of Coleoptera and Diptera in terms of numbers/m^2 at Station 2 over the study period.

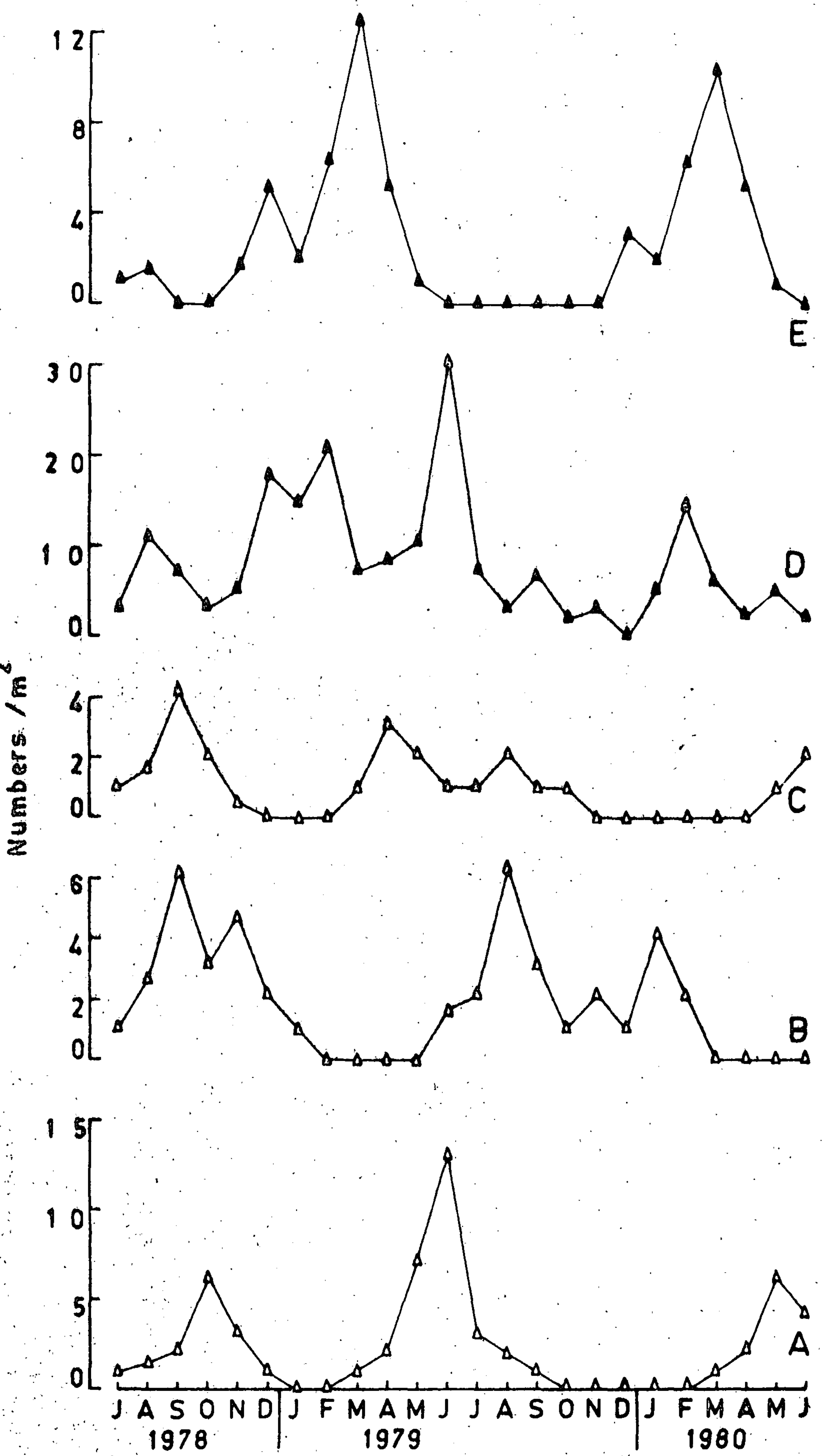
A - Dytiscidae

B - Hydrophilidae

C - Gyrinidae

D - Chironomidae

E - Culicidae



12
8
4
0
E
30
20
10
0
D
Numbers /m²
4
2
0
C
6
4
2
0
B
15
10
5
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 20

Figure 21 : Showing the biomass of various families of Coleoptera and Diptera in terms of weight (mg)/m^2 at Station 2 over the study period.

A - Dytiscidae

B - Hydrophilidae

C - Gyrinidae

D - Chironomidae

E - Culicidae

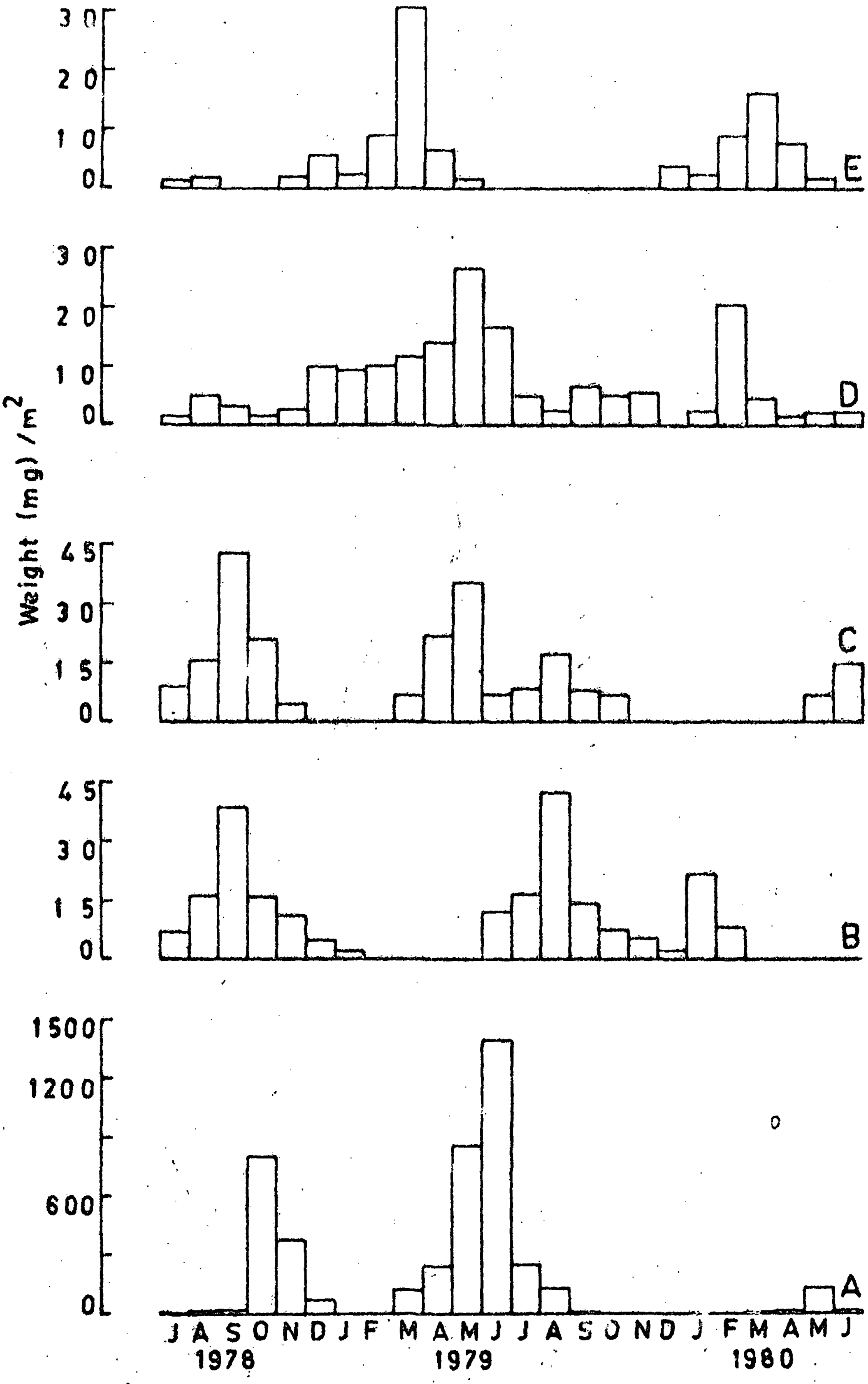

Weight (mg) /m²
E
D
C
B
A
30
20
10
0
45
15
1500
1200
600
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 21

TABLE-3 : Showing the density (no./m^2) of various species of insects at Station 2 over the study period.

Insect species :

1. *Anisops batillifrons* Lundblad
2. *Agraptocorixa hyalinipennis* Fabr.
3. *Micronecta* sp.
4. *Ranatra filiformis* Fabr.
5. *Neogerris parvulus* Stal
6. *Limnogonus nitidus* Mayr.
7. *Diplonychus rusticus* Fabr.
8. *Cloeon* sp.1
9. *Caenis* sp.
10. *Tramea similata* Rmb.
11. *Lestes* sp.
12. Unidentified Coenagrionidae
13. *Laccophilus* sp.
14. *Guignotus* sp.
15. *Cybister* sp.
16. *Rhantus pulverosus* Stephens
17. *Berosus pulchellus* W.M'Leay
18. *Enochrus* sp.
19. *Dineutus unidentatus* Aube
20. *Gyrinus smaragdinus* Regimbart
21. *Polypedilum* sp.
22. Unidentified Culicidae

TABLE-3

Insect species	1978						1979												1980					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1.	11.5	22.4	56.2	46.9	30.7	9.4	5.2	3.1	4.2	2.1	7.3	10.4	14.6	22.9	17.7	61.5	25.0	28.1	8.3	3.1	2.1	13.5	7.3	20.8
2.	6.3	13.0	8.3	5.2	6.2	3.1	1.0	1.0	-	-	-	4.7	16.7	10.4	4.2	5.2	2.1	2.1	1.0	-	-	-	3.1	8.3
3.	-	-	2.1	3.1	6.8	22.9	8.3	4.2	1.0	-	-	2.1	1.0	4.2	5.7	7.3	17.7	9.4	3.1	5.2	2.1	-	1.0	3.1
4.	-	0.5	2.1	3.1	1.6	1.0	1.0	-	-	-	1.0	1.0	2.1	1.0	-	-	1.0	-	-	-	-	-	-	1.0
5.	2.1	-	-	2.1	10.4	7.3	5.2	3.1	1.0	2.1	2.1	-	1.0	2.1	4.2	2.1	8.3	3.1	1.0	2.1	-	-	-	1.0
6.	-	3.1	5.2	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.	2.1	4.7	3.1	1.0	-	-	-	-	-	-	-	1.6	1.0	3.1	7.3	5.2	1.0	2.1	-	-	-	-	-	-
8.	18.8	8.3	5.2	16.7	10.4	22.9	15.6	29.2	9.4	4.2	2.1	11.5	7.3	16.7	9.4	5.2	10.4	8.3	25.0	10.4	3.1	6.3	7.3	12.5
9.	3.1	1.0	-	1.0	2.6	3.1	5.2	1.0	-	-	-	1.0	3.1	2.1	1.0	3.1	7.3	4.2	2.1	2.1	-	-	-	2.1
10.	1.0	3.1	5.2	2.1	7.3	4.2	2.1	-	-	1.0	-	2.1	5.2	4.2	9.9	5.2	3.1	1.0	-	-	-	-	2.1	4.2
11.	5.2	2.6	2.1	1.0	-	-	-	-	-	-	-	1.6	3.1	5.2	7.8	2.1	4.2	1.0	-	-	-	-	-	2.1
12.	3.1	7.3	9.4	5.2	3.6	7.3	4.2	1.0	2.1	-	-	-	1.0	4.2	7.8	5.2	2.1	1.0	3.1	8.3	2.1	1.0	-	1.0
13.	1.0	0.5	-	-	-	-	-	-	-	-	3.1	5.7	1.0	1.0	-	-	-	-	-	-	1.0	2.1	4.2	2.1
14.	-	1.0	2.1	5.2	2.6	-	-	-	-	-	2.1	3.6	-	-	1.0	-	-	-	-	-	-	-	1.0	2.1
15.	-	-	-	1.0	0.5	-	-	-	-	-	1.0	1.6	-	-	-	-	-	-	-	-	-	-	-	-
16.	-	-	-	-	-	1.0	-	-	1.0	2.1	1.0	2.1	2.1	1.0	-	-	-	-	-	-	-	-	1.0	-
17.	1.0	2.6	5.2	2.1	-	-	-	-	-	-	-	1.6	2.1	6.3	3.1	1.0	-	-	-	-	-	-	-	-
18.	-	-	1.0	1.0	4.7	2.1	1.0	-	-	-	-	-	-	-	-	-	2.1	1.0	4.2	2.1	-	-	-	-
19.	1.0	1.6	4.2	2.1	0.5	-	-	-	-	-	-	-	1.0	2.1	1.0	-	-	-	-	-	-	-	-	-
20.	-	-	-	-	-	-	-	-	1.0	3.1	2.1	1.0	-	-	-	1.0	-	-	-	-	-	-	1.0	2.1
21.	3.1	10.9	7.3	3.1	5.2	17.7	14.6	20.8	7.3	8.3	10.4	30.2	7.3	3.1	6.7	2.1	3.1	-	5.2	14.6	6.3	2.1	5.2	2.1
22.	1.0	1.6	-	-	1.6	5.2	2.1	6.3	12.5	5.2	1.0	-	-	-	-	-	-	3.1	2.1	6.3	10.4	5.2	1.0	-

and February '80 (29.3 mg/m^2), of the first and second cycles respectively (Figure 15-E).

Diptera was represented by two families : Chironomidae and Culicidae.

Chironomidae was more abundant than Culicidae and as such indicated fluctuations similar to Diptera (Figure 20-D). The density peaks were observed in February '79 (20.8/m^2), June '79 (30.2/m^2) and February '80 (14.6/m^2). The family was recorded throughout the study period except in December '79. The biomass showed its peaks only in May '79 (26.5 mg/m^2) and February '80 (20.3 mg/m^2) (Figure 21-D). The family was represented by Polypedilum sp.

The density of Culicidae ranged between 0.0 and 12.5/m^2 (Figure 20-E). The maximum values were seen in March (12.5/m^2 and 10.4/m^2) in both the annual cycles. They recorded absence during September to October '78, June to November '79 and June '80. Biomass data indicated peaks in March of both annual cycles, though the first was higher (30.3 mg/m^2) than the second (16.3 mg/m^2) (Figure 21-E). The family was represented by larval stages which could not be identified.

(iii) Kyrdemkulai Fish Pond (Station 3) :

The seasonal abundance and standing crop (biomass) were recorded for a period of two annual cycles in this station. No collection could be made in the month of April '79 as the pond was almost dry.

Hemiptera :

The fluctuations of Hemiptera population differed slightly from the pattern recorded in Stations 1 and 2 (Figure 22-A).

During the first annual cycle, the density indicated only a small pulse in October '78 (57.2/m^2). The second cycle recorded the peak in September '79 (93.7/m^2) and again a small rise in April '80 (63.5/m^2). The minimum values were noted in March '79 (15.6/m^2) and February '80 (15.7/m^2) during the first and second cycles respectively. The standing crop however, indicated peak values in August '78 (747.9 mg/m^2) in the first cycle and September '79 (1083.5 mg/m^2) and April '80 (598.7 mg/m^2) in the second cycle (Figure 23-A).

As in Station 2, Hemiptera was represented by five families: Notonectidae, Corixidae, Nepidae, Gerridae and Belostomatidae.

Notonectidae recorded the highest density among the families of Hemiptera (Figure 24-A). It indicated the same trend as Hemiptera with maxima in October '78 (47.9/m^2), September '79 (62.5/m^2) and April '80 (54.2/m^2). Minimum density was estimated at 9.4/m^2 (December '78 and February '79) during the first cycle and 7.3/m^2 (February '80), during the second cycle. Biomass showed a slight shift in the first cycle, with the peak of increase recorded in August '78 (611.0 mg/m^2) (Figure 25-A). The second cycle however showed the same trend as density, with maxima in September '79 (505.2 mg/m^2) and April '80 (513.4 mg/m^2). The family included two species: Enithares ciliata and Anisops batillifrons. The latter recorded higher density values (40.6/m^2) than the former (25.0/m^2). Both species showed late summer and spring maxima and winter minima (Table-4).

The pattern of fluctuations in Corixidae was similar to Notonectidae except for the slight shift in peak values (Figure 24-B). The density ranged between nil and 20.3/m^2. Highest densities were seen in August '78 ($18.2/m^2$) during the first cycle and September '79 ($20.3/m^2$) and May '80 ($14.6/m^2$) during the second cycle. No specimen was collected during February '79 and January to March '80. The standing crop record reflected the same trend with peaks in August '78 (126.1 mg/m^2), September '79 (88.4 mg/m^2) and May '80 (43.6 mg/m^2) (Figure 25-B). The family was listed by two species : Agraptoxorixa hyalinipennis and Micronecta sp. The former ($16.7/m^2$) recorded higher density values than the latter ($8.3/m^2$). Although both the species mostly indicated summer or late-summer maxima, they recorded somewhat irregular seasonal fluctuations (Table-4).

Nepidae represented the lowest density values among the families of Hemiptera (Figure 24-C). It also showed irregular seasonal fluctuations and was absent during August to September '78, February to August '79, January to March '80 and May to June '80. The maximum density value of $5.2/m^2$ was recorded in October '79. However, the family revealed higher biomass values similar to Notonectidae (Figure 25-C). The first cycle recorded small peaks in July '78 (278.0 mg/m^2) and October '78 (286.8 mg/m^2). The maximum biomass was recorded in the second cycle in October '79 (648.4 mg/m^2) similar to their density. The family included two species: Ranatra filiformis and Laccotrephes grossus. The latter was collected only on three occasions: July '78, October '78 and October '79.

The next family Gerridae indicated distinct winter maxima and summer minima, although it had restricted occurrence (Figure 24-D). The maximum values were noticed during January '79 ($18.7/m^2$) and December '79 ($15.6/m^2$) of the first and second annual cycles respectively. The family recorded nil values during July '78, May to August '79, April to June '80. Biomass data revealed the same trend recording maximum values in January '79 (68.9 mg/m^2) and December '79 (92.2 mg/m^2) of the first and second cycles respectively (Figure 25-D). The family had two representatives : Neogerris parvulus and Limnogonus nitidus. The former (14.5/m^2) was more abundant than the latter (4.2/m^2) (Table-4).

Belostomatidae was completely absent during the first annual cycle, but recorded throughout the second cycle (Figure 24-E). The maximum density was seen in December '79 (19.8/m^2) and the minimum in June '80 (1.0/m^2). However, the biomass recorded peak values in September '79 (17.8 mg/m^2) and December '79 (18.1 mg/m^2) (Figure 25-E). The family was represented by a single species : Diplonychus rusticus.

Ephemeroptera :

The population of Ephemeroptera in this station differed from Station 1 and 2, in that it indicated an autumn and spring maxima (Figure 22-B). The peak of increase was marked in November '78 (53.6/m^2) of the first cycle and October '79 (52.1/m^2) and May '80 (67.8/m^2) of the second cycle. Minimum values were noticed in September '78 (2.1/m^2) and February '80 (4.2/m^2) of the first and second cycles. Data for standing crop also showed the same trend as density, recording peak values in November '78 (102.5 mg/m^2), October '79 (80.3 mg/m^2) and May '80 (196.5 mg/m^2), the latter representing the maximum (Figure 23-B). The order was represented by a single family Baetidae which included Cloeon sp.1.

Odonata :

Among all the orders of this station, Odonata recorded the highest values, in terms of both density and biomass. Unlike in other two stations, the density indicated a winter maxima and summer minima (Figure 22-C). The maximum density was seen in November '78 (182.7/m^2) during the first cycle. The minimum for the same period was noted in May '79 (8.8/m^2). The maximum during the second cycle was recorded in December '79 (126.1/m^2). The biomass record however indicated quite a different trend with high increase in September '78 (1782.0 mg/m^2), March '79 (2613.4 mg/m^2), October '79 (3191.4 mg/m^2) and April '80 (1375.5 mg/m^2) (Figure 23-C).

Odonata was represented by four families : Libellulidae, Aeshnidae, Lestidae and Coenagrionidae.

Libellulidae indicated the same trend as Odonata except for a slight shift in peak values (Figure 26-B). The first cycle recorded the maximum in November '78 (98.4/m^2), while in the second cycle it was in October '79 (71.9/m^2). The minimum values were recorded in May (5.2/m^2 and 6.3/m^2) in both the annual cycles. Biomass data however did not reflect the above trend (Figure 27-B). Peaks in biomass were seen in September '78 (1396.7 mg/m^2), March '79 (1966.3 mg/m^2), October '79 (1904.8 mg/m^2) and April '80 (1090.0 mg/m^2). The family had only one representative : *Tramea similata*.

Aeshnidae represented the lowest density of all the families of Odonata, beside showing an irregular seasonal fluctuations (Figure 26-C). It recorded nil values during July '78, December '78 to July '79, and January to May '80. The peak was noted in September '78 (4.2/m^2) and October '79 (6.3/m^2) of the first and second annual cycles respectively. Standing crop estimation revealed also a small pulse in September '78 (262.5 mg/m^2) with the peak in October-November '79 (1072.7 mg/m^2 and 1058.0 mg/m^2) (Figure 27-C). The family was represented by a single species : Anax nigrofasciatus nigrolinatus.

The next family Lestidae differed slightly from Libellulidae in its fluctuations (Figure 26-D). The magnitude of variation was also much lower than the latter. The first cycle recorded a maximum in November '78 (21.4/m^2), while the second cycle revealed a peak in September '79 (17.2/m^2). The family recorded nil values during May and June '79. The minimum value during the second cycle was recorded in March '80 (2.1/m^2). The biomass estimation indicated quite a different trend with highest values in October '78 (245.6 mg/m^2), January '79 (227.9 mg/m^2), January '80 (226.9 mg/m^2) and June '80 (201.6 mg/m^2) (Figure 27-D). This family includes Lestes sp.

Like Odonata, Coenagrionidae also recorded winter maxima and summer minima (Figure 26-E). Peaks were recorded in December (86.4/m^2 and 77.1/m^2) in both the annual cycles. Minimum values were recorded in May '79 (3.6/m^2) and July '79 (5.2/m^2) of the first and second annual cycles. The biomass however showed two large pulses in the first annual cycle- one in December '78 (560.8 mg/m^2) and the other in March '79 (596.3 mg/m^2) (Figure 27-E). The second cycle failed to indicate any pronounced peak. The family included a single unidentified species.

Coleoptera :

During the first annual cycle, the population of Coleoptera showed a decrease initially, reaching the lowest in September

'78 (1.0/m^2) (Figure 22-D). Subsequently the density recorded an increase except for a slight fall in January and March '79. A peak was attained in June '79 (25.1/m^2) followed by rapid decrease. Except for December '79, the density showed a downward trend till January '80, only to rise again rapidly to reach the maximum abundance in April '80 (31.2/m^2). Thereafter, the density declined. The biomass revealed a slightly different trend with a small pulse in February '79 (389.3 mg/m^2) and a peak in May '80 (796.6 mg/m^2) (Figure 23-D).

The order Coleoptera comprised of three families : Dytiscidae, Hydrophilidae and Gyrinidae.

The fluctuations of Dytiscidae population was almost similar to Coleoptera (Figure 28-A). The density remained very low during July '78 to March '79, recording nil values in September and October '78. The peak values were noted in June '79 and May '80 (21.9/m^2) of the first and second annual cycles respectively. Nil value was noted in November '79 of the second cycle. Thus a summer maxima and autumn minima was recorded for this family. The biomass however, indicated a small peak in January '79 (243.3 mg/m^2) in the first cycle and a large one in May '80 (766.3 mg/m^2) in the second.(Figure 29-A). The family included the following species : Laccophilus sp., Hydraticus vittatus and Cybister sp. Laccophilus represented the maximum density (13.0/m^2) followed by Cybister (11.5/m^2). All the three species showed irregular seasonal fluctuations with their non-occurrence in several months during the entire study period (Table-4).

Hydrophilidae recorded irregular seasonal fluctuations (Figure 28-B). It was most abundant in November '78 (9.4/m^2) and

April '80 ($8.3/m^2$). A small rise in number was also indicated in July '79 ($5.2/m^2$). The family recorded nil values during July to September '78, May '79, September '79 to November '79 and January '80. The biomass estimation showed similar trend as the density with maxima in November '78 (56.9 mg/m^2), July '79 (33.1 mg/m^2) and April '80 (43.6 mg/m^2) (Figure 29-B). The family comprised of two species: Berosus pulchellus and Enochrus sp. B. pulchellus was more abundant of the two species.

Gyrinidae had its maximum pulse in February '79 ($12.5/m^2$) in the first year and December '79 ($9.4/m^2$) and April '80 ($7.3/m^2$) of the second (Figure 28-C). It recorded nil values in July '78, July and August '79. The standing crop also revealed the same trend with a peak in February '79 (203.8 mg/m^2) in the first year and smaller pulses in December '79 (79.0 mg/m^2) and April '80 (63.3 mg/m^2) of the second year (Figure 29-C). Gyrinidae was represented by Gyrinus smaragdinus and Dineutus unidentatus. The former was more abundant ($10.4/m^2$) than the latter, which occurred only during February '79 to June '79 (Table-4).

Diptera :

The population of Diptera showed wide fluctuations, with density ranging from $2.1/m^2$ to $57.9/m^2$ (Figure 22-E). The peak of increase was noticed in November '78 ($57.9/m^2$) and June '79 ($52.1/m^2$) in the first annual cycle, and April '80 ($49.0/m^2$) in the second annual cycle. Minima were seen in August '78 ($2.6/m^2$) and June '80 ($2.1/m^2$). The biomass recorded nearly the same pattern with their highest in November '78 (29.8 mg/m^2), March '79 (42.0 mg/m^2) and June '79 (25.0 mg/m^2) in the first cycle and April '80 (53.0 mg/m^2) in the second cycle (Figure 23-E). Diptera was represented by two families : Chironomidae and Culicidae.

Figure 22 : Showing the density of various orders of insects in terms of numbers/m^2 at Station 3 over the study period.

A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera

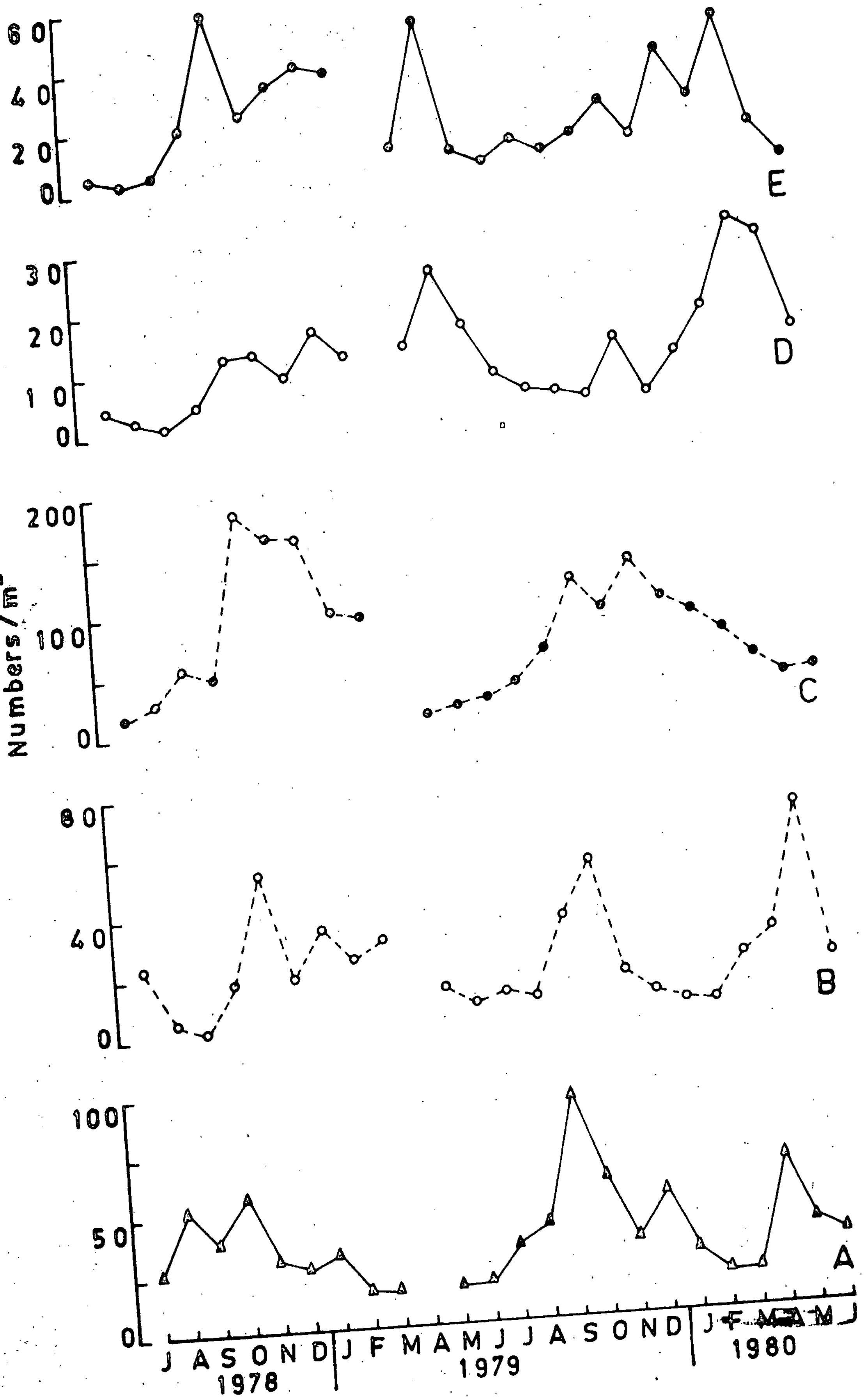

Numbers / m²
60
40
20
0
E
30
20
10
0
D
200
100
0
C
80
40
0
B
100
50
0
A
J A S O N D
1978
J F M A M J J A S O N D
1979
J F M A M J
1980

Fig.22

Figure 23 : Showing the biomass of various orders of insects in terms of weight (mg)/m^2 at Station 3 over the study period.

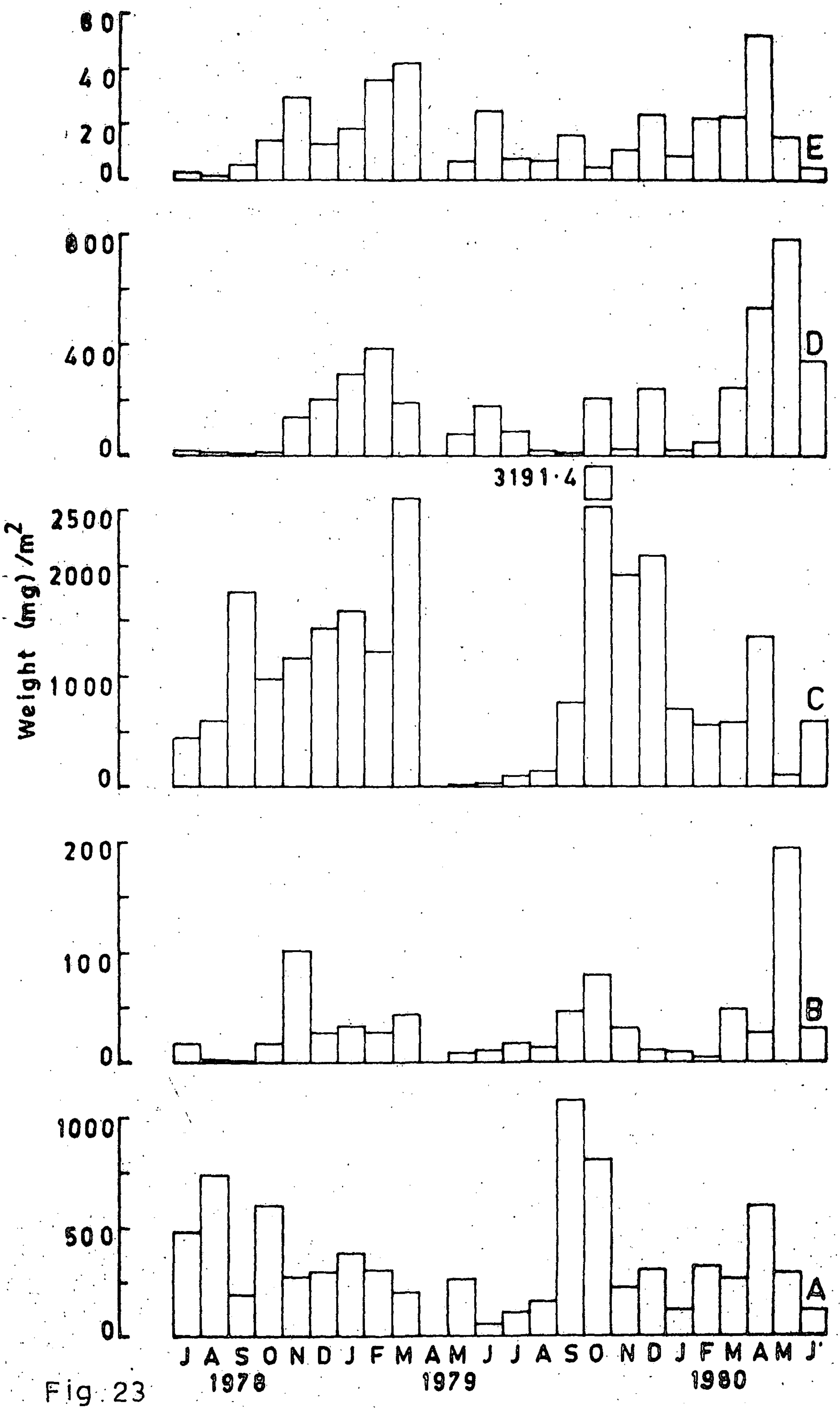
A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera



60
40
20
0
E
800
400
0
D
3191·4
2500
2000
1000
0
C
Weight (mg)/m²
200
100
0
B
1000
500
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 23

Figure 24 : Showing the density of various families of Hemiptera in terms of number/m^2 at Station 3 over the study period.

A - Notonectidae

B - Corixidae

C - Nepidae

D - Gerridae

E - Belostomatidae

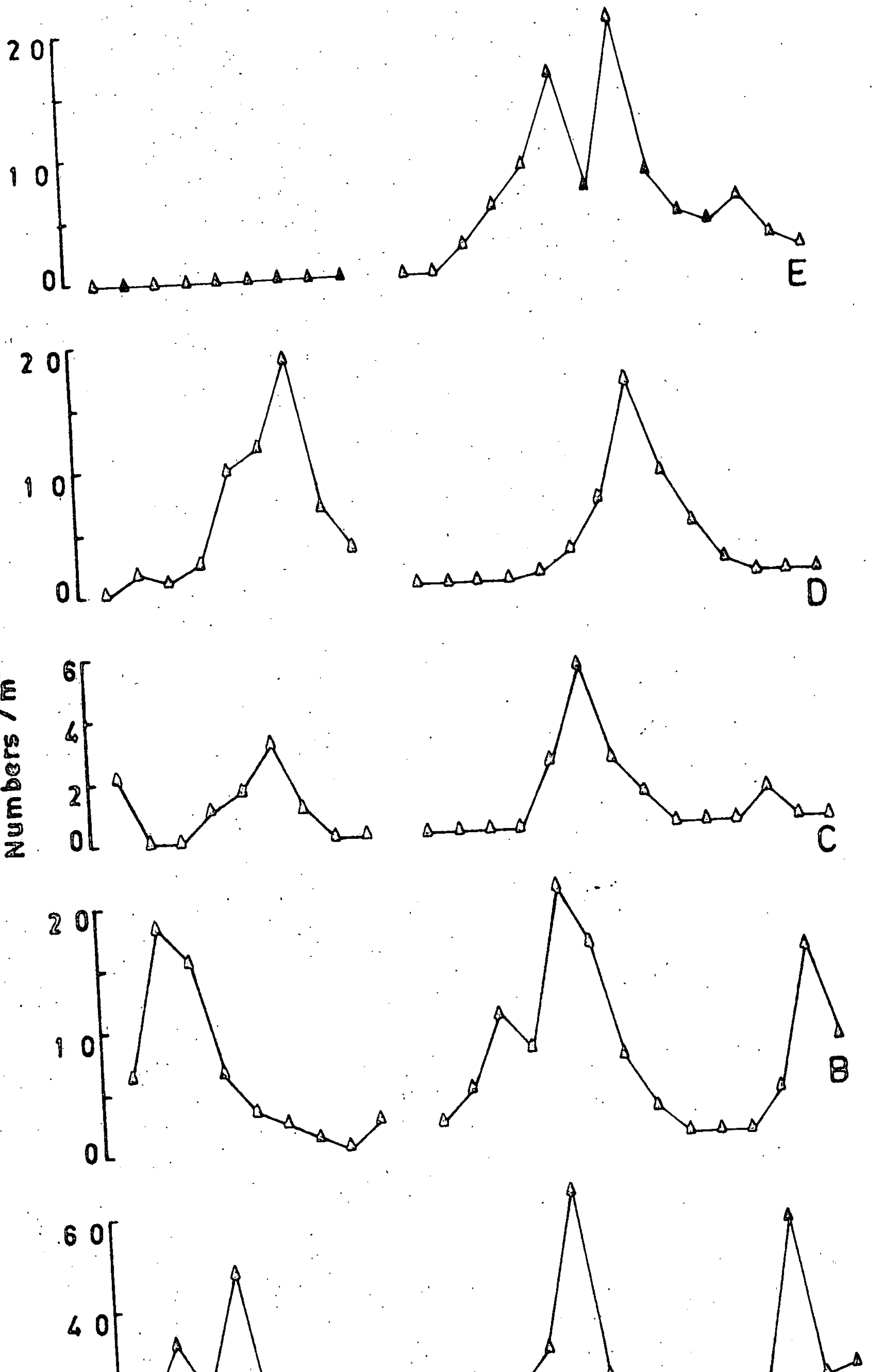

Numbers / m2
20
10
0
E
20
10
0
D
6
4
2
0
C
20
10
0
B
60
40
20
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 24

Figure 25 : Showing the biomass of various families of Hemiptera in terms of weight (mg)/m^2 at Station 3 over the study period.

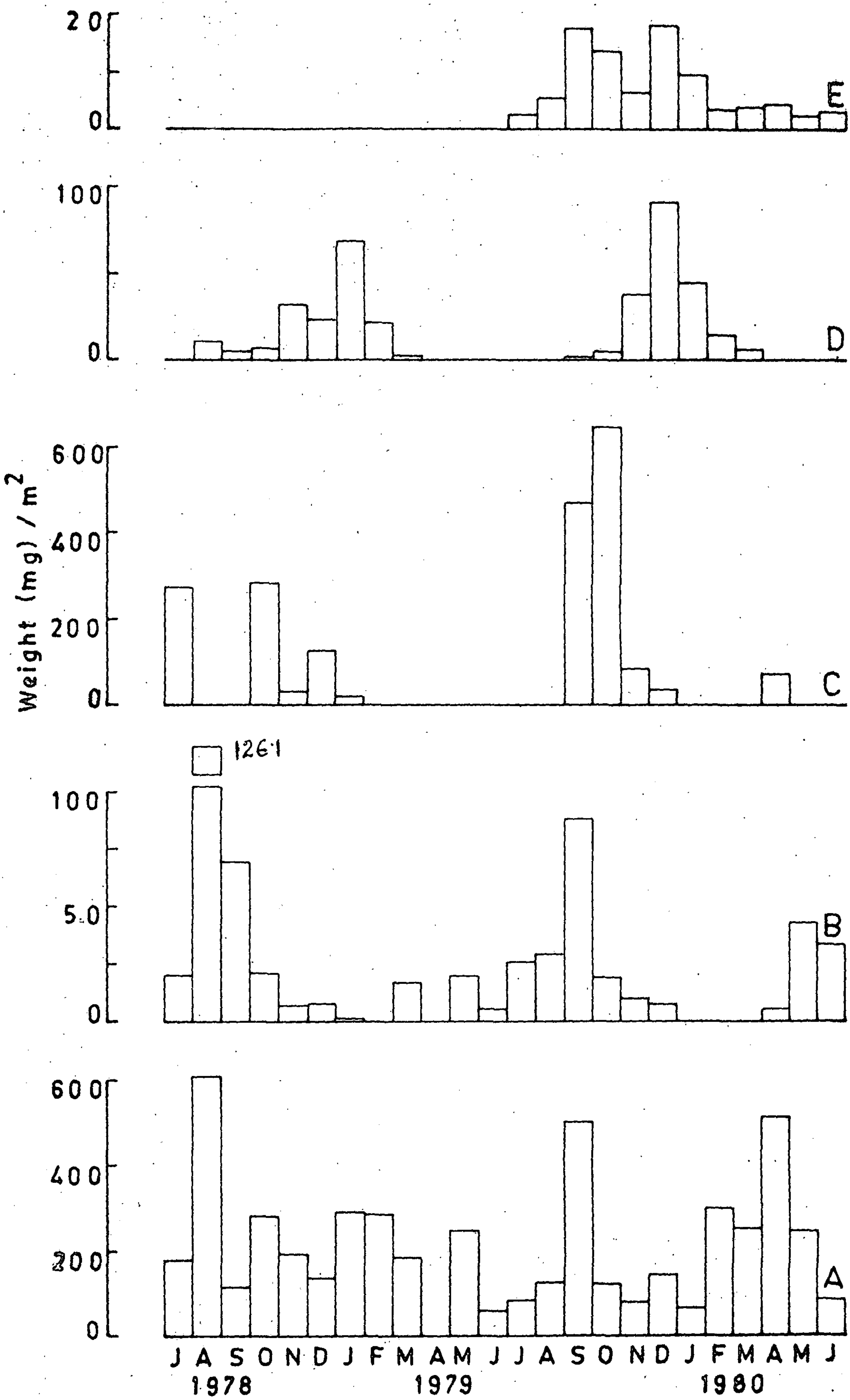
A - Notonectidae

B - Corixidae

C - Nepidae

D - Gerridae

E - Belostomatidae



20
0
E
100
0
D
600
400
200
0
C
Weight (mg) / m²
126·1
100
5.0
0
B
600
400
200
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 25

Figure 26 : Showing the density of various families of Ephemeroptera and Odonata in terms of number/m^2 at Station 3 over the study period.

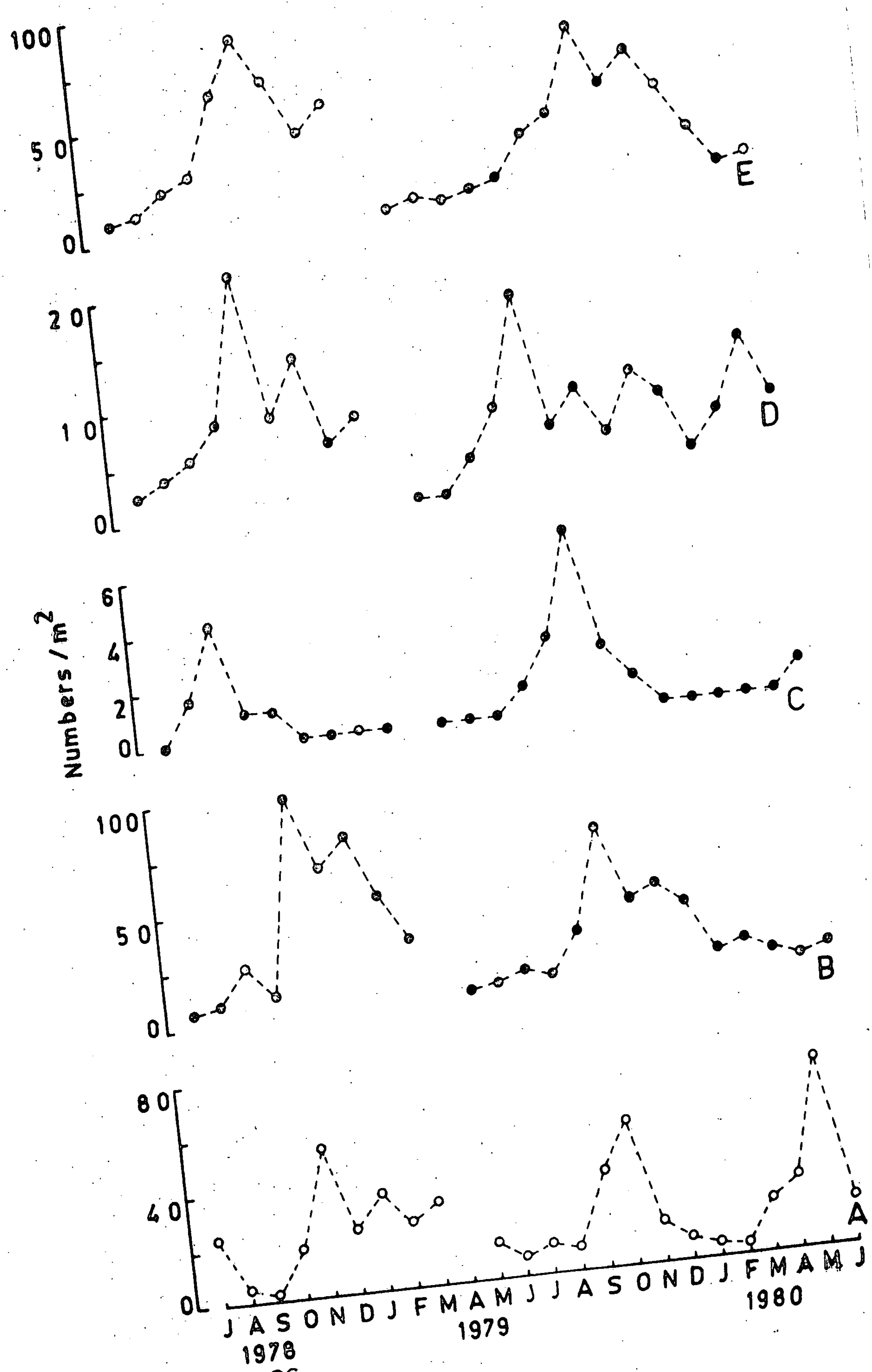
A - Baetidae

B - Libellulidae

C - Aeshnidae

D - Lestidae

E - Coenagrionidae



100
50
0
E
20
10
0
D
6
4
2
0
C
Numbers / m2
100
50
0
B
80
40
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 26

Figure 27 : Showing the biomass of various families of Ephemeroptera and Odonata in terms of weight $(mg)/m^2$ at Station 3 over the study period.

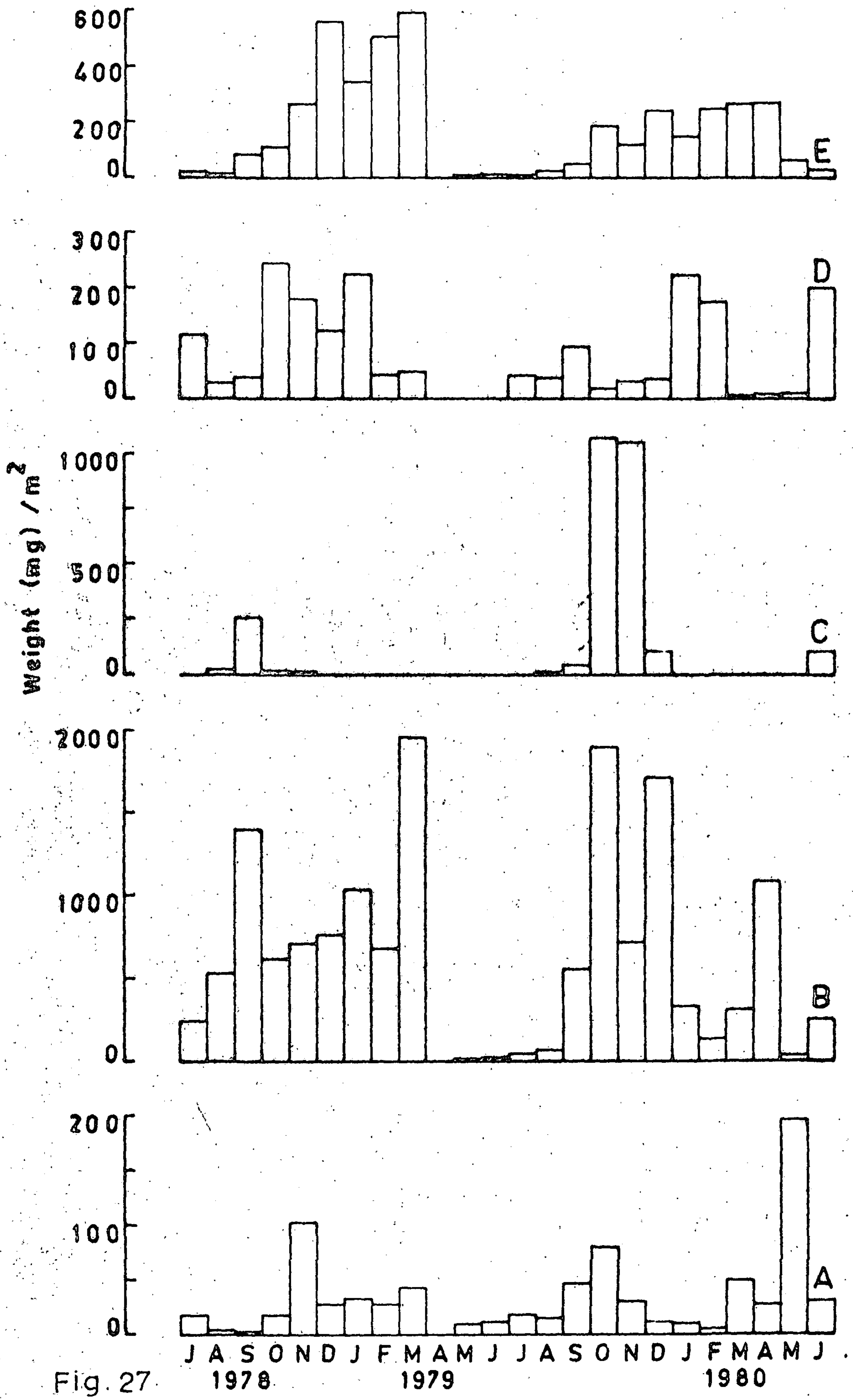
A - Baetidae

B - Libellulidae

C - Aeshnidae

D - Lestidae

E - Coenagrionidae



Weight (mg) / m²
E
D
C
B
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 27

Figure 28 : Showing the density of various families of Coleoptera and Diptera in terms of number/m^2 at Station 3 over the study period.

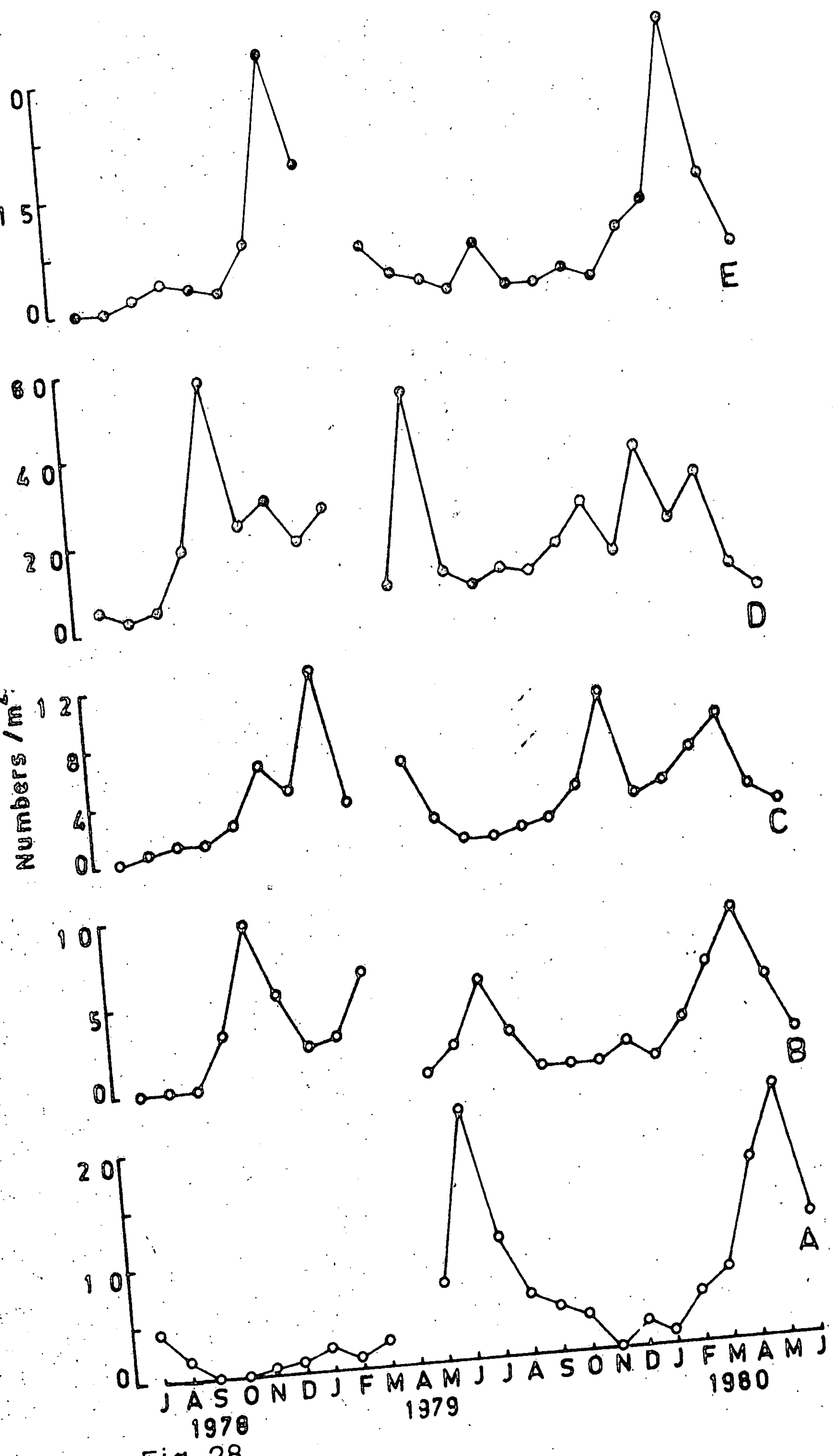
A - Dytiscidae

B - Hydrophilidae

C - Gyrinidae

D - Chironomidae

E - Culicidae



20
15
0
E
60
40
20
0
D
Numbers /m2
12
8
4
0
C
10
5
0
B
20
10
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 28

Figure 29 : Showing the biomass of various families of Coleoptera and Diptera in terms of weight (mg)/m^2 at Station 3 over the study period.

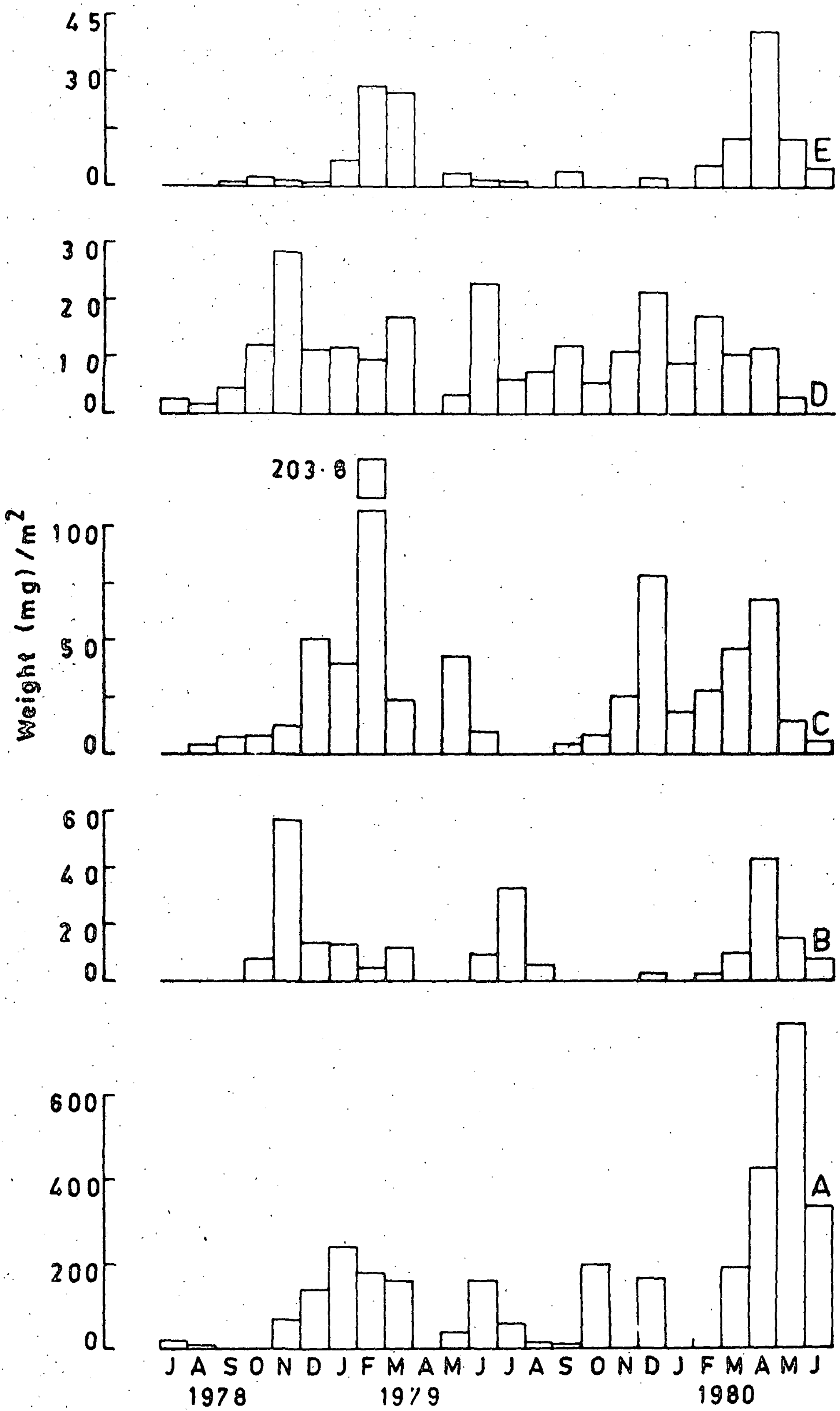
A - Dytiscidae

B - Hydrophilidae

C - Gyrinidae

D - Chironomidae

E - Culicidae



E
D
C
B
A
45
30
0
30
20
10
0
203·8
100
50
0
60
40
20
0
600
400
200
0
Weight (mg)/m²
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 29

TABLE-4 : Showing the density (no./m^2) of various species of insects at Station 3 over the study period.

Insect species :

1. Enithares ciliata Fabr.
2. Anisops batillifrons Lundblad
3. Agraptocorixa hyalinipennis Fab.
4. Micronecta sp.
5. Ranatra filiformis Fabr.
6. Laccotrephes grossus Fabr.
7. Neogerris parvulus Stal.
8. Limnogonus nitidus Mayr.
9. Diplonychus rusticus Fabr.
10. Cloeon sp.1
11. Tramea similata Rmb.
12. Anax nigrofasciatus nigrolinatus Fraser
13. Unidentified Coenagrionidae
14. Lestes sp.
15. Laccophilus sp.
16. Hydraticus vittatus (Fab).
17. Cybister sp.
18. Berosus pulchellus W.M'Leay
19. Enochrus sp.
20. Gyrinus smaragdinus Regimbart
21. Dineutus unidentatus Aube.
22. Polypedilum sp.
23. Anatopynia sp.
24. Unidentified Culicidae.

TABLE-4

Insect species	1978						1979												1980					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1.	8.3	25.0	10.4	7.3	3.1	2.1	6.3	5.2	2.6	-	4.2	5.2	5.2	9.4	22.9	7.3	5.2	8.3	2.1	5.2	5.2	18.8	8.3	5.2
2.	9.4	7.8	11.5	40.6	12.5	7.3	5.2	4.2	7.8	-	10.4	7.3	14.6	18.7	39.6	13.5	6.3	5.2	8.3	2.1	7.3	35.4	11.5	16.7
3.	4.2	15.1	8.3	3.1	1.0	-	-	-	2.1	-	1.6	2.6	-	5.2	16.7	7.3	3.1	-	-	-	-	3.1	14.6	6.3
4.	2.1	3.1	7.3	3.1	2.1	2.1	1.0	-	-	-	-	1.6	-	2.1	3.6	8.3	3.1	2.1	-	-	-	-	-	1.0
5.	-	-	-	-	1.6	3.1	1.0	-	-	-	-	-	-	-	2.1	4.2	2.1	1.0	-	-	-	1.0	-	-
6.	2.1	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
7.	-	1.6	1.0	2.1	7.8	9.4	14.5	5.7	3.1	-	-	-	-	-	0.5	2.1	6.3	12.5	7.3	4.2	1.0	-	-	-
8.	-	-	-	-	2.1	2.1	4.2	1.0	-	-	-	-	-	-	-	-	-	3.1	1.0	-	-	-	-	-
9.	-	-	-	-	-	-	-	-	-	-	-	-	2.1	5.2	8.3	15.6	6.3	19.8	7.3	4.2	3.1	5.2	2.1	1.0
10.	23.9	5.2	2.1	17.7	53.6	22.9	34.4	23.9	30.2	-	13.0	6.8	10.4	8.3	34.4	52.1	14.6	8.0	5.2	4.2	18.8	26.0	67.8	16.7
11.	6.3	9.4	25.0	11.4	98.4	65.6	79.2	50.5	30.7	-	5.2	7.3	11.5	8.3	26.0	71.9	38.5	43.8	25.4	12.5	15.6	10.4	6.3	10.4
12.	-	1.6	4.2	1.0	1.0	-	-	-	-	-	-	-	-	1.0	2.6	6.3	2.1	1.0	-	-	-	-	-	1.0
13.	8.3	11.9	20.8	27.1	61.9	86.4	66.7	41.1	54.2	-	3.6	7.8	5.2	9.4	12.5	31.3	39.6	77.1	50.0	63.5	46.9	27.1	10.4	12.5
14.	2.1	3.6	5.2	8.3	21.4	8.3	13.5	5.7	7.8	-	-	-	3.1	7.3	17.2	5.2	8.3	4.2	9.4	7.3	2.1	5.2	11.5	6.3
15.	2.1	1.6	-	-	-	-	-	-	0.5	-	2.6	13.0	4.2	2.1	2.1	1.0	-	-	1.0	4.2	3.1	10.4	7.3	2.1
16.	-	-	-	-	0.5	1.0	2.1	1.0	1.6	-	-	-	-	-	-	2.1	-	2.1	-	-	1.0	2.1	3.1	2.1
17.	2.1	-	-	-	-	-	-	-	-	-	4.2	8.9	6.2	3.1	2.1	-	-	-	-	-	2.1	3.1	11.5	6.3
18.	-	-	-	3.1	9.4	5.2	2.1	1.0	2.6	-	-	1.6	5.2	2.1	-	-	-	1.0	-	-	2.1	7.3	4.2	1.0
19.	-	-	-	-	-	-	-	1.6	3.6	-	-	-	-	-	-	-	-	-	-	2.1	3.1	1.0	-	-
20.	-	0.5	1.0	1.0	2.1	6.3	4.2	10.4	2.1	-	2.6	-	-	-	0.5	1.0	3.1	9.4	2.1	3.1	5.2	7.3	2.1	1.0
21.	-	-	-	-	-	-	-	2.1	1.0	-	3.1	1.6	-	-	-	-	-	-	-	-	-	-	-	-
22.	5.2	2.6	4.2	9.4	14.1	5.2	3.1	1.0	5.7	-	-	-	-	5.2	8.3	3.1	6.2	11.5	4.2	1.0	3.1	-	-	-
23.	-	-	-	8.3	42.2	17.7	25.0	17.2	19.8	-	6.3	50.5	8.3	-	-	4.2	7.3	10.4	6.2	33.3	13.6	27.1	5.2	-
24.	-	-	1.0	2.1	1.6	1.0	5.2	21.4	11.5	-	4.2	1.6	1.0	-	3.6	-	-	1.0	-	4.2	6.3	21.9	8.3	2.1

Chironomidae showed fluctuations almost similar to Diptera (Figure 28-D). The first year indicated two pulses in November '78 ($56.3/m^2$) and June '79 ($50.5/m^2$), the former being the maximum density. The second cycle however recorded a small peak in February '80 ($34.3/m^2$). August '78 ($2.6/m^2$) and June '80 ($0.0/m^2$) recorded the minimum values during the first and second cycles respectively. A similar pattern was seen in biomass record with high values in November '78 ($28.3\ mg/m^2$), June '79 ($23.1\ mg/m^2$) and December '79 ($21.5\ mg/m^2$) (Figure 29-D). The family included Polypedilum sp. and Anatopynia sp. The latter recorded higher density ($50.5/m^2$) than the former ($14.1/m^2$). Both the species showed irregularity in their fluctuations being absent in some months in both the annual cycles (Table-4).

Culicidae represented its peak of abundance in February '79 ($21.41/m^2$) in the first cycle (Figure 28-E). The peak however shifted to April '80 ($21.9/m^2$) in the second cycle. There was total absence of the members of this family during July to August '78 in the first year and August '79, October to November '79 and January '80 in the second year. The biomass reached their peak values in February-March '79 ($26.8\ mg/m^2$ and $24.9\ mg/m^2$) and April '80 ($41.3\ mg/m^2$) (Figure 29-E). As in other two stations the family included only larval stqges which were not identified.

(iv) Ulubari Fish Pond (Station 4) :

The seasonal abundance and standing crop (biomass) of the five insect orders in Ulubari Fish Pond was recorded for a period of two annual cycles.

Hemiptera :

The Hemiptera represented the highest density and biomass among all the orders in this station. The density fluctuations recorded a summer maxima and a spring minima (Figure 30-A). During the first cycle, there was a slight increase initially reaching a small pulse in September '78 ($102.1/m^2$). In the subsequent months, except for a minor increase in December '78, the density indicated a downward trend to reach the lowest value in April '79 ($14.6/m^2$). However, it again rose sharply through June '79, attaining maximum abundance in July '79 ($276.0/m^2$) in the second cycle, followed by a steep fall immediately. The density remained comparatively low during the autumn and winter months recording a minimum of $22.8/m^2$ in February '80 of the second cycle. A sharp increase was again indicated in June '80 ($146.9/m^2$). The biomass estimation recorded a slightly different trend with peaks in January '79 (1609.0 mg/m^2), July '79 (1636.9 mg/m^2) and April '80 (1955.6 mg/m^2), the latter representing the maximum value (Figure 31-A).

Hemiptera comprised of six families : Notonectidae, Corixidae, Nepidae, Pleidae, Gerridae and Belostomatidae.

Notonectidae recorded the highest density ($168.2/m^2$) with overall preponderance among the families of Hemiptera (Figure 32-A). This was reflected in its seasonal fluctuations, which indicated the same trend as was seen in Hemiptera. Thus, the density showed little change from August to May in the first cycle, except reaching the lowest value in April ($7.3/m^2$). In the second cycle, July recorded the peak with the highest density. A high density value was also seen in June ($120.8/m^2$) in the second cycle. The standing crop revealed a different trend with a peak in January '79 (1072.6 mg/m^2), a small rise in July '79 (705.7

mg/m^2) and the peak in April '80 (1910.5 mg/m^2) (Figure 33-A). This family had a single representative: Anisops bouvieri.

The fluctuations of Corixidae population differed from that of Notonectidae. The density ranged between $4.1/m^2$ to $94.2/m^2$ (Figure 32-B). It peaked in September '78 ($84.4/m^2$) and December '78 ($54.2/m^2$) during the first cycle and July '79 ($94.2/m^2$) of the second cycle. Minimum values were recorded in April '79 ($4.2/m^2$) and February '80 ($4.1/m^2$) of the two cycles respectively. The biomass record revealed the same trend with high values in September '78 (284.8 mg/m^2), December '78 (263.2 mg/m^2) and July '79 (159.3 mg/m^2) (Figure 33-B). The family comprised of : Agraptocorixa hyalinipennis and Micronecta sp. The latter ($66.7/m^2$) recorded a higher density than the former ($43.2/m^2$). Both species showed the same trend as Corixidae (Table-5).

The next family Pleidae was recorded only in this station (Figure 32-C). It showed an irregular seasonal fluctuation, occurring only in a few months during the entire period of study. It indicated a peak in density in February '79 ($15.6/m^2$) and March '80 ($17.7/m^2$) of the first and second cycles respectively. Members of this family recorded nil during July '78, September to November '78, May to December '79 and May to June '80. Similar trends were reflected for the biomass estimation with maximum values in February '79 (18.5 mg/m^2) and March '80 (21.0 mg/m^2) (Figure 33-D). The family was represented by a single species : Plea areolata.

The remaining families- Nepidae, Gerridae and Belostomatidae also showed irregular seasonal fluctuations occurring only in few months during both the annual cycles.

The family Nepidae representing low density was recorded during July '78 to February '79, and June '79 to January '80 (Figure 32-D). A maximum value of $5.2/m^2$ was noted in August '78 and July '79. The biomass however recorded a different trend, with peak values indicated in November-December '78 ($645.6\ mg/m^2$ and $616.9\ mg/m^2$) and December '79-January '80 ($711.3\ mg/m^2$ and $704.0\ mg/m^2$) (Figure 33-C). The family was represented by Ranatra filiformis and Laccotrephes grossus. The latter was collected only on four occasions during the entire study period.

Gerridae also showed low density (Figure 32-E). It was recorded during July '78 to January '79 and July '79 to February '80. Maximum values were noticed in August ($6.3/m^2$ and $5.2/m^2$) in both annual cycles. The biomass revealed its peaks in August '78 ($18.3\ mg/m^2$), August '79 ($13.1\ mg/m^2$) and December '79 ($12.3\ mg/m^2$) (Figure 33-E). The family was represented by a single species : Neogerris parvulus.

The last family Belostomatidae also indicated low density comparable to Nepidae and Gerridae. The family was recorded during July to October '78 and May to September '79 (Figure 32-F). Maximum values were noted in August '78 ($5.7/m^2$) and July '79 ($6.3/m^2$). However, the family revealed biomass values far higher than Gerridae and Pleidae. Peaks in biomass were seen during August-September '78 ($261.5\ mg/m^2$ and $246.3\ mg/m^2$) and July '79 ($645.6\ mg/m^2$), the latter representing the maximum biomass (Figure 33-F). The family included a single species: Diplonychus rusticus.

Ephemeroptera :

The population density of Ephemeroptera ranged between $4.2/m^2$ to $54.2/m^2$ (Figure 30-B). The first cycle registered gradual decline from July '78 ($25.0/m^2$) onwards, but recovered through the winter months to attain a small rise in February '79 ($25.0/m^2$). Thereafter, the density showed decrease till April '79 ($4.2/m^2$) to reach the lowest value. In subsequent months, there was sharp increase towards a large peak in June '79 ($54.2/m^2$), followed by a decrease. The second cycle, recorded maximum values ($35.4/m^2$) during December '79 and June '80. The minimum during the same period was noted in October ($8.4/m^2$). A summer and winter maxima with autumn and spring minima was recorded for this order. Biomass record revealed its peak values in June '79 (78.8 mg/m^2), December '79 ($52.3/mg^2$) and June '80 (53.9 mg/m^2) (Figure 31-B).

Ephemeroptera was represented by two families : Baetidae and Caenidae.

Baetidae showed a decreasing trend from July '78 onwards in the first cycle, recording nil values in February '79 (Figure 34-A). Thereafter, the density increased gradually and then rapidly till it reached a peak in June '79 ($54.2/m^2$). The second cycle recorded the maximum value in June '80 ($32.3/m^2$). Minimum value for the same period was seen in January '80 ($2.1/m^2$). Biomass showed almost the same trend with peaks of increase recorded in June '79 (78.8 mg/m^2) and June '80 (53.9 mg/m^2) of the first and second annual cycle respectively (Figure 35-A). The family was represented by a single species : Cloeon sp.2.

The population of Caenidae recorded a distinct winter maxima and summer minima (Figure 34-B). The density ranged between nil and $27.1/m^2$. Maximum values were recorded in February '79 ($25.0/m^2$) and December '79 ($27.1/m^2$) of the first and second cycles respectively. It recorded nil values during July to September '78, April to June '79, August to September '79 and May to June '80. The biomass revealed its peaks in February '79 (34.6 mg/m^2) and December '79 (29.3 mg/m^2) (Figure 35-B). The family included Caenis sp.

Odonata :

Odonata represented lowest density among all the orders in this station (Figure 30-C). It showed a summer maxima and spring minima. In the first cycle, the density recorded a gradual decrease from July '78 (30.2/m^2) till March '79, when it reached the lowest value (1.6/m^2). Subsequently it increased rapidly and a peak was attained in August '79 (36.5/m^2), in the second cycle, followed by a steady decline. The downward trend continued till April '80 to record a value of 2.0/m^2. Thereafter, the density rose again through May and June '80. The standing crop record indicated a different trend with highest values in July-August '78 (838.4 mg/m^2 and 803.6 mg/m^2) and December '79 (753.5 mg/m^2) (Figure 31-C).

Odonata comprised of two families : Libellulidae and Coenagrionidae.

Libellulidae represented lower density than Coenagrionidae, fluctuating between nil and 8.3/m^2 (Figure 34-D). Maximum values were recorded in December (7.3/m^2 and 8.3/m^2) in both annual cycles. The family was present throughout the study period except in May '80. The peak in biomass was however observed in August '78 (651.0 mg/m^2) and December '79 (654.4 mg/m^2) (Figure 35-C). The family was represented by : Orthetrum sp.

Coenagrionidae indicated the same trend as Odonata (Figure 34-C). Maximum values were seen in July '78 (25.0/m^2) of the first cycle and August '79 (34.4/m^2) and June '80 (26.0/m^2) of the second cycle. No members of Coenagrionidae was recorded during February to April '79. Standing crop revealed almost the same trend with peaks in July '78 (301.7 mg/m^2), July '79 (342.2 mg/m^2) and June '80 (306.6 mg/m^2) (Figure 35-D). The family was represented by a single unidentified species.

Coleoptera :

The population of Coleoptera differed from other stations, recording an autumn and winter maxima and spring minima (Figure 30-D). It had two maxima in September '78 (44.8/m^2) and February '79 (62.5/m^2) in the first cycle and February '80 (44.7/m^2) in the second cycle. Minimum values were seen in May (2.0/m^2 and 2.1/m^2) in both the annual cycles. Data for the biomass revealed the same trend with a small rise in September '78 (273.4/mg^2) and larger pulses in January-February (988.5 mg/m^2, 950.4 mg/m^2) and February '80 (914.7 mg/m^2) (Figure 31-D).

Coleoptera comprised of four families : Dytiscidae, Hydrophilidae, Noteridae and Gyrinidae.

Dytiscidae population showed fluctuations similar to Coleoptera (Figure 36-A). It indicated its peak of increase in September '78 (43.8/m^2) and February '79 (51.0/m^2) in the first cycle, and February '80 (34.3/m^2) of the second cycle. Nil values were recorded in May in both cycles. The biomass revealed a small rise in September '78 (272.1 mg/m^2), and large pulses in January-February (862.1 mg/m^2 and 898.5 mg/m^2) and February '80 (835.4

mg/m^2) (Figure 37-A). The family was represented by four species: Laccophilus sindensis, Laccophilus flexuosus, Hyphoporus elevatus and Cybister sp. Among these, L. flexuosus indicated the maximum density ($30.2/m^2$) followed by L. sindensis ($22.4/m^2$). The other two species were present in very low numbers. Cybister sp. was collected only on three occasions during the entire study period. H. elevatus was recorded during January to March '79 and December '79 to February '80. No specimens of L. sindensis were collected during April to September '79, November '79 to January '80 and April to June '80 (Table-5).

The population of Hydrophilidae fluctuated between 0.0 and $16.7/m^2$ (Figure 36-B). The peak of increase was seen in January ($16.7/m^2$ and $15.7/m^2$) in both annual cycles. Nil values were recorded during July to October '78, August '79 and May to June '80. The biomass revealed the same trend as density, with peak values in January (116.9 mg/m^2 and 75.8 mg/m^2) in both the years (Figure 37-B). The family was represented by Berosus fairmairei, Berosus pulchellus, Regimbartia attenuata and Enochrus sp. All the species showed irregular seasonal fluctuations, with their presence restricted to few months during the annual cycles. B. fairmairei recorded the maximum density ($12.0/m^2$) among the four species. R. attenuata and Enochrus sp. were recorded only on four and five occasions respectively (Table-5).

The other two families Noteridae and Gyrinidae showed very low densities. Noteridae was recorded only in this station. It revealed its maximum values in August ($4.7/m^2$ and $6.3/m^2$) in both the cycles (Figure 36-C). It recorded nil values during January to June '79, December '79 to January '80 and March to

June '80. The standing crop showed the same trend with peak values observed in August (9.1 mg/m^2 and 13.2 mg/m^2) in both cycles (Figure 37-C). The family was listed by a single species: Canthydrus laetabilis.

The family Gyrinidae was recorded during January to May '79 and December '79 to May '80 (Figure 36-D). It had peaks in March (5.2/m^2 and 6.3/m^2), in both the cycles. The standing crop recorded the peak in March '79 (121.4 mg/m^2) with a small pulse in March '80 (57.7 mg/m^2) (Figure 37-D). The family was represented by a single species : Dineutus unidentatus.

Diptera :

The Diptera revealed a winter maxima and a summer minima in its seasonal fluctuations (Figure 30-E). Maximum abundance was observed in December (114.0/m^2 and 85.5/m^2) in both the annual cycles. Minimum values were recorded in July (3.1/m^2) and February (4.1/m^2) in the first and second cycles respectively. Biomass estimation recorded a large peak in December '78 (272.6 mg/m^2) and a small peak in December '79 (98.0 mg/m^2) (Figure 31-E).

Diptera included the families Chironomidae and Culicidae.

Chironomidae was far more abundant than Culicidae. The population fluctuated between a minimum of 3.1/m^2 and a maximum of 108.3/m^2 (Figure 34-E). The trend of fluctuation was similar to Diptera, with a peak in density recorded in December (108.3/m^2 and 79.2/m^2) during the two annual cycles. The biomass revealed its peak of increase in December (257.4 mg/m^2 and 87.2 mg/m^2) in both the cycles (Figure 35-E). The family was represented by Chironomus sp. and Tanypus sp. Chironomus (93.7/m^2) was more

Figure 30 : Showing the density of various orders of insects in terms of number/m^2 at Station 4 over the study period.

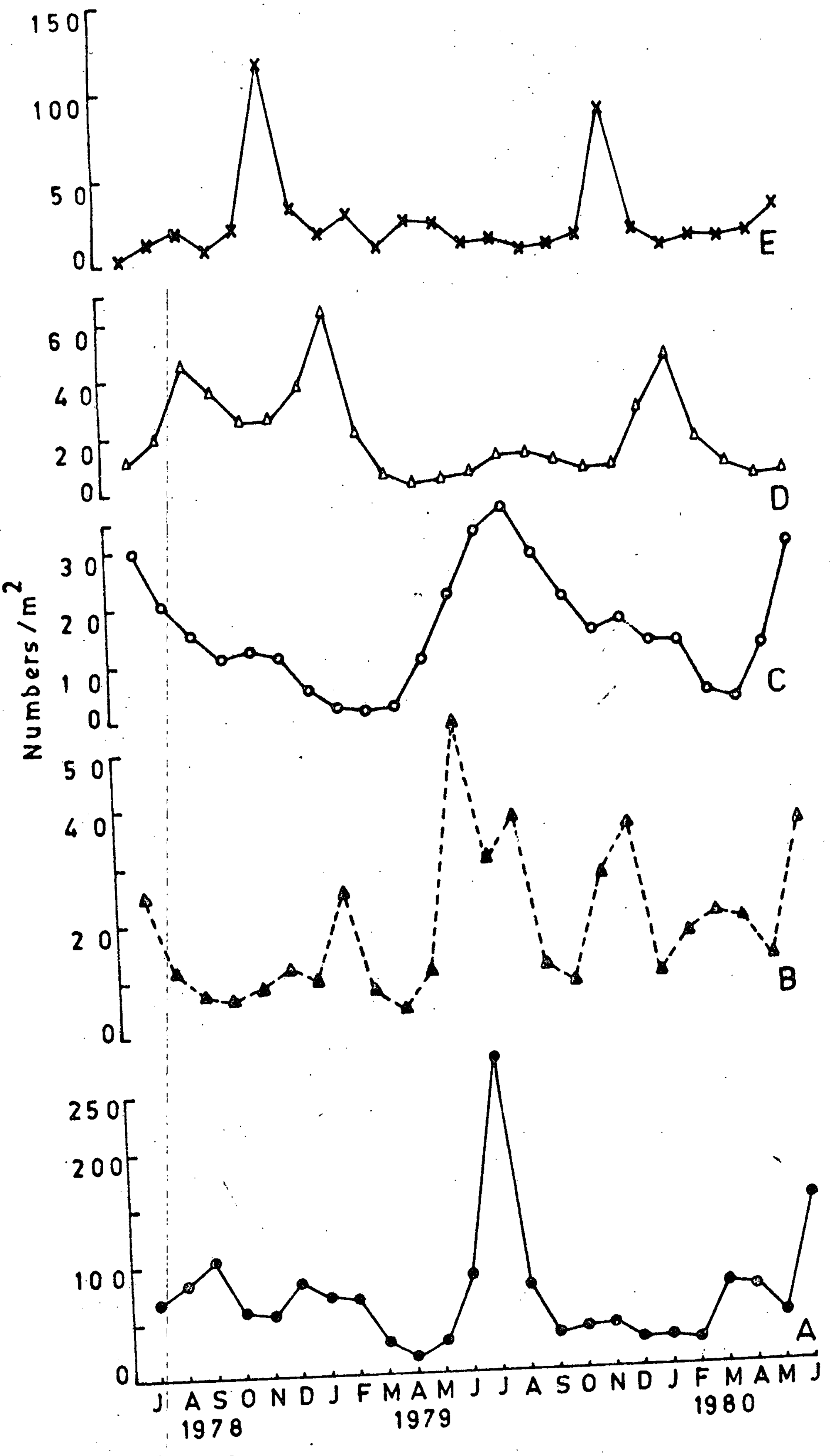
A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera



150
100
50
0
E
60
40
20
0
D
30
20
10
0
C
Numbers/m²
50
40
20
0
B
250
200
100
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 30

Figure 31 : Showing the biomass of various orders of insects in terms of weight (mg)/m^2 at Station 4 over the study period.

A - Hemiptera

B - Ephemeroptera

C - Odonata

D - Coleoptera

E - Diptera

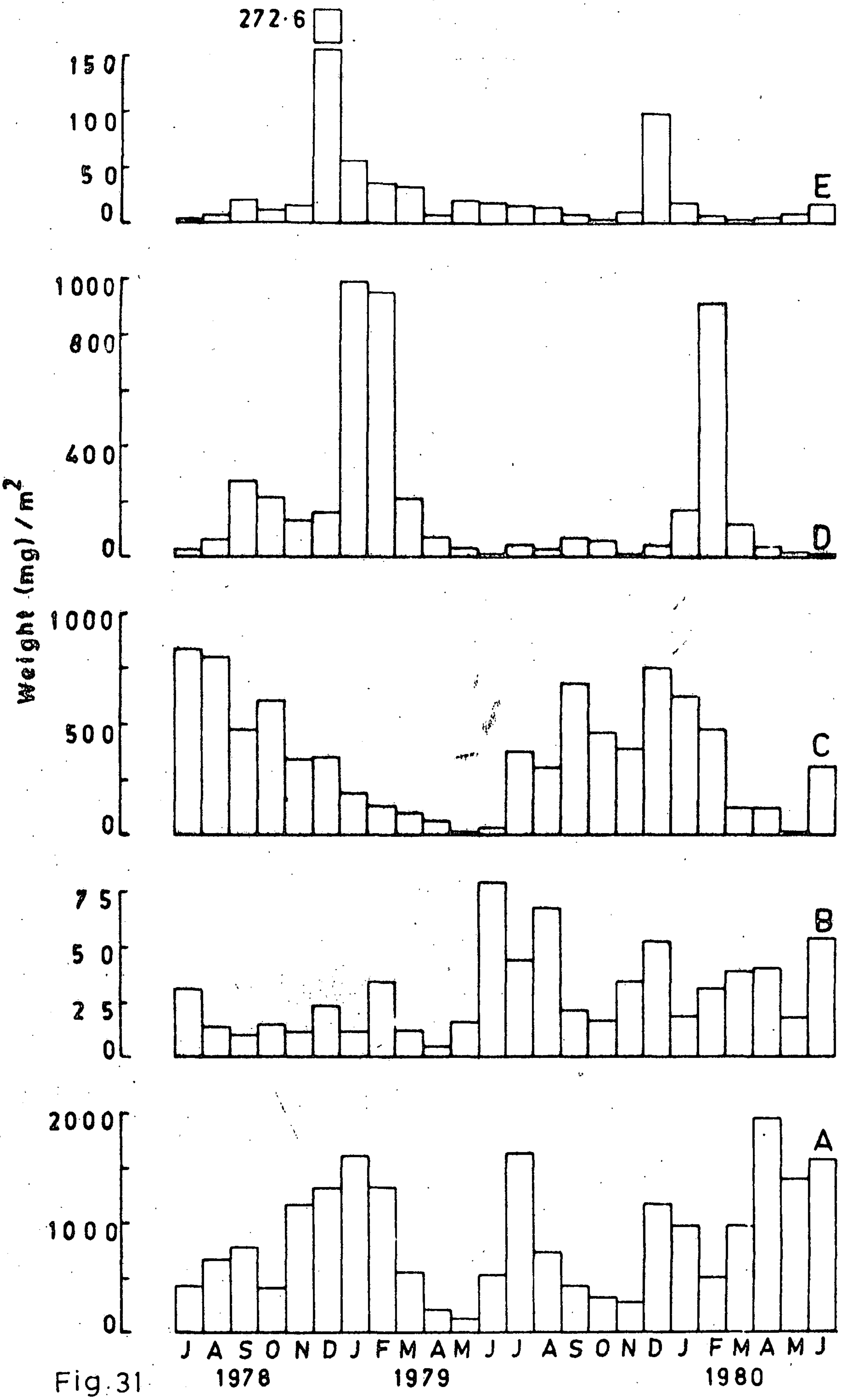

272·6
150
100
50
0
E
1000
800
400
0
D
Weight (mg)/m²
1000
500
0
C
75
50
25
0
B
2000
1000
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig.31

Figure 32 : Showing the density of various families of Hemiptera in terms of number/m^2 at Station 4 over the study period.

A - Notomectidae

B - Corixidae

C - Pleidae

D - Nepidae

E - Gerridae

F - Belostomatidae

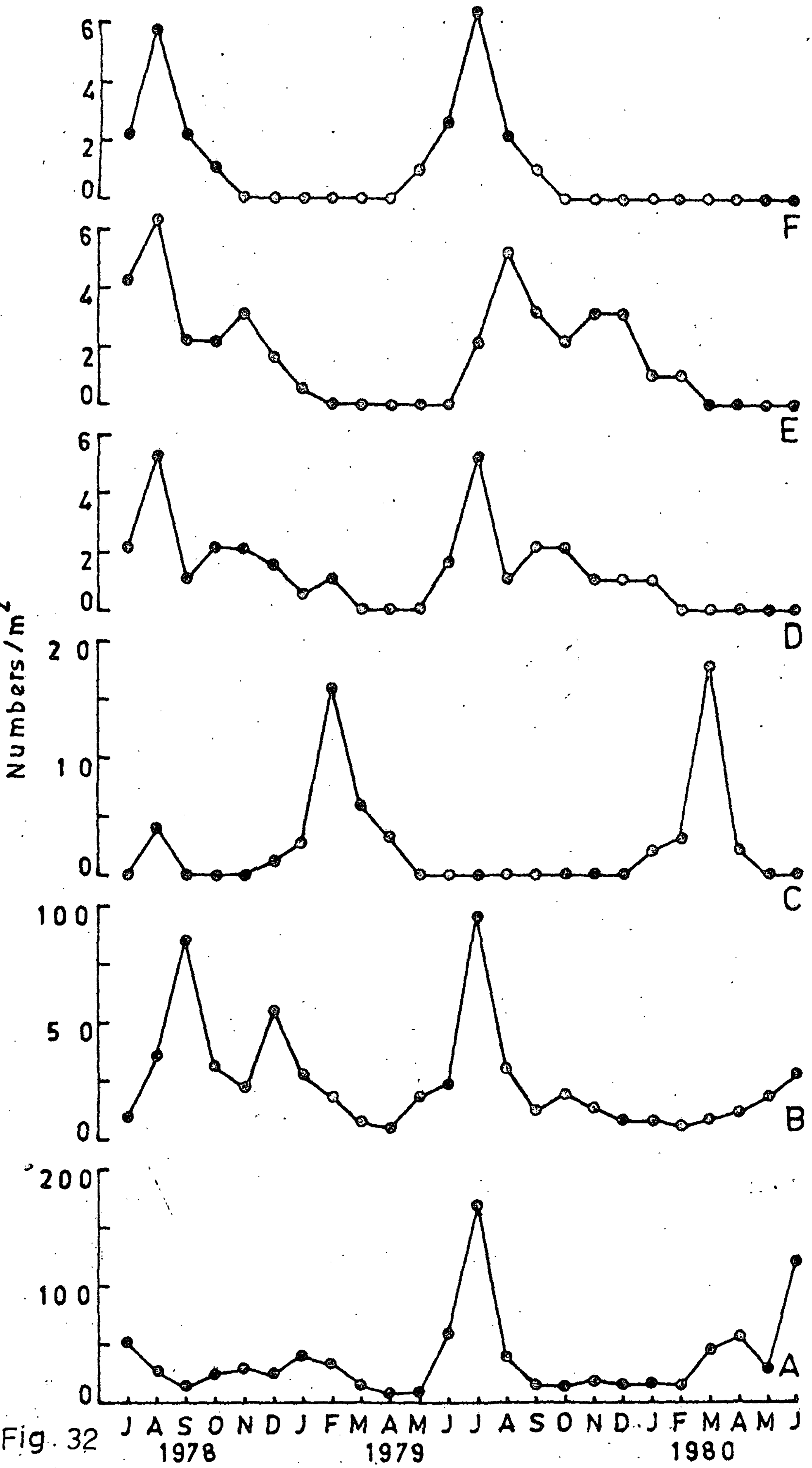

Numbers/m2
6
4
2
0
F
6
4
2
0
E
6
4
2
0
D
20
10
0
C
100
50
0
B
200
100
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 32

Figure 33 : Showing the biomass of various families of Hemiptera in terms of weight (mg)/m^2 at Station 4 over the study period.

A - Notonectidae

B - Corixidae

C - Nepidae

D - Pleidae

E - Gerridae

F - Belostomatidae

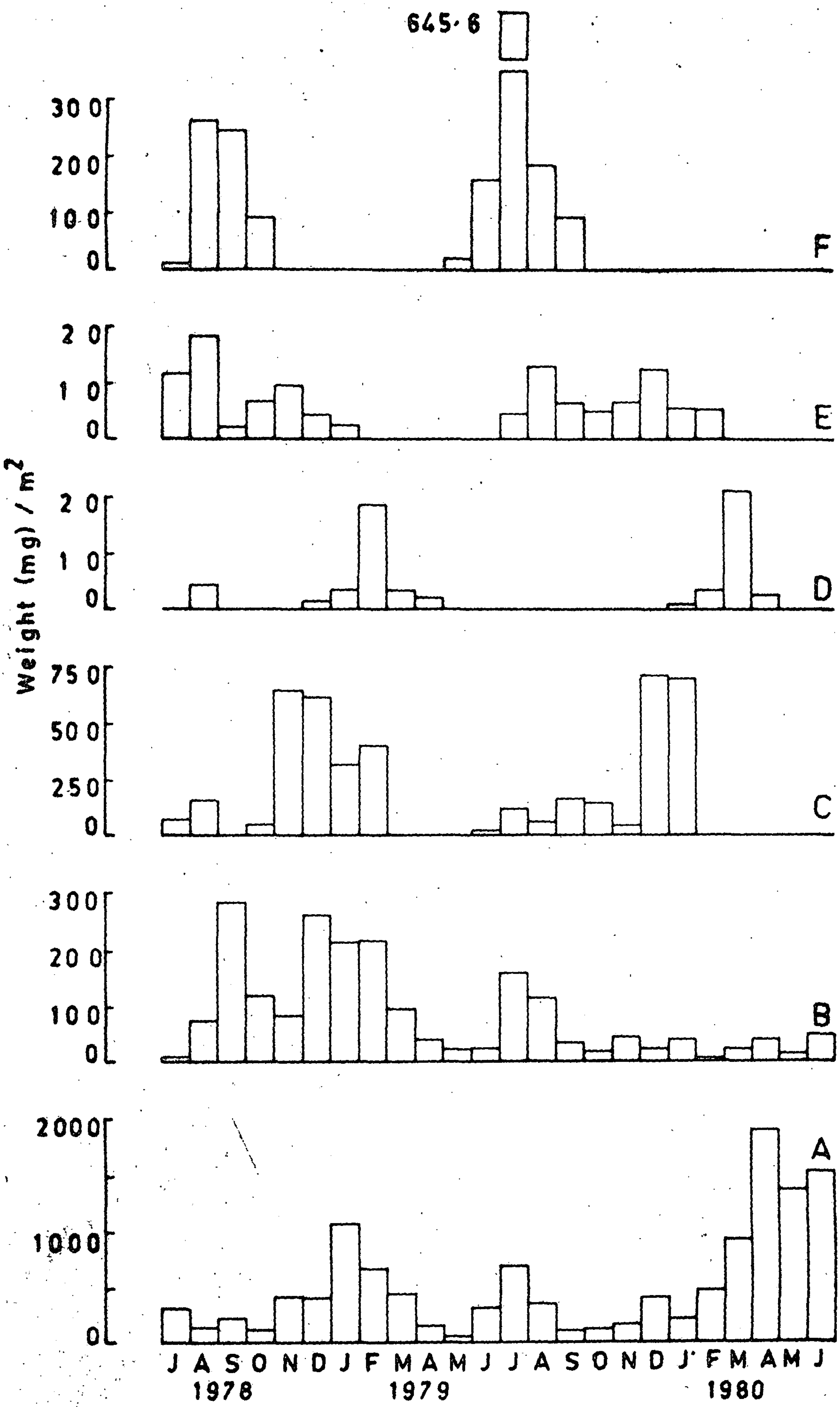

645·6
300
200
100
0
F
20
10
0
E
20
10
0
D
Weight (mg) / m2
750
500
250
0
C
300
200
100
0
B
2000
1000
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 33

Figure 34 : Showing the density of various families of Ephemeroptera, Odonata and Diptera in terms of number/m^2 at Station 4 over the study period.

A - Baetidae

B - Caenidae

C - Coenagrionidae

D - Libellulidae

E - Chironomidae

F - Culicidae

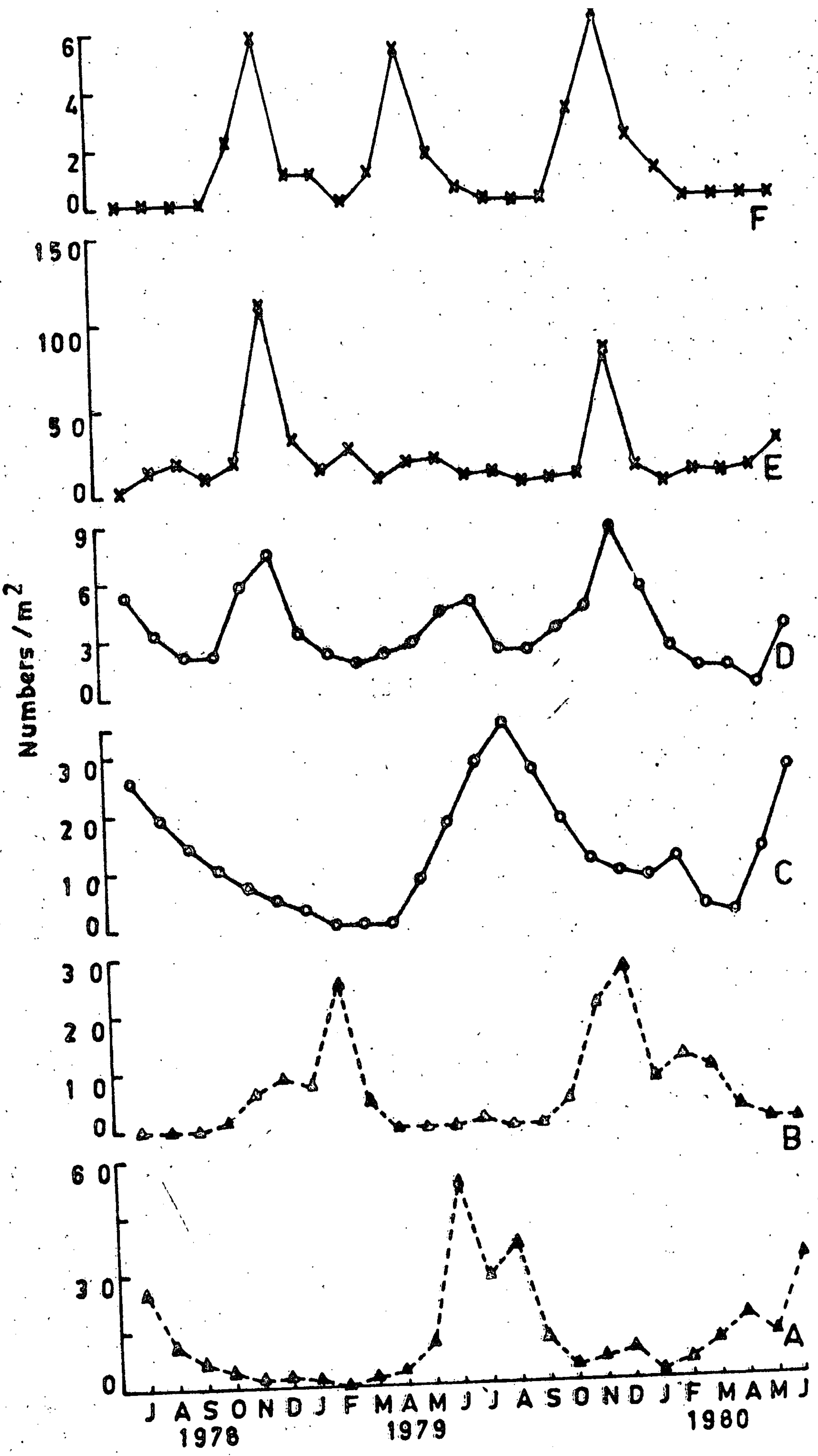

F
E
D
C
B
A
Numbers / m²
0
2
4
6
50
100
150
3
9
10
20
30
60
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 34

Figure 35 : Showing the biomass of various families of Ephemeroptera, Odonata and Diptera in terms of weight (mg)/m^2 at Station 4 over the study period.

A - Baetidae

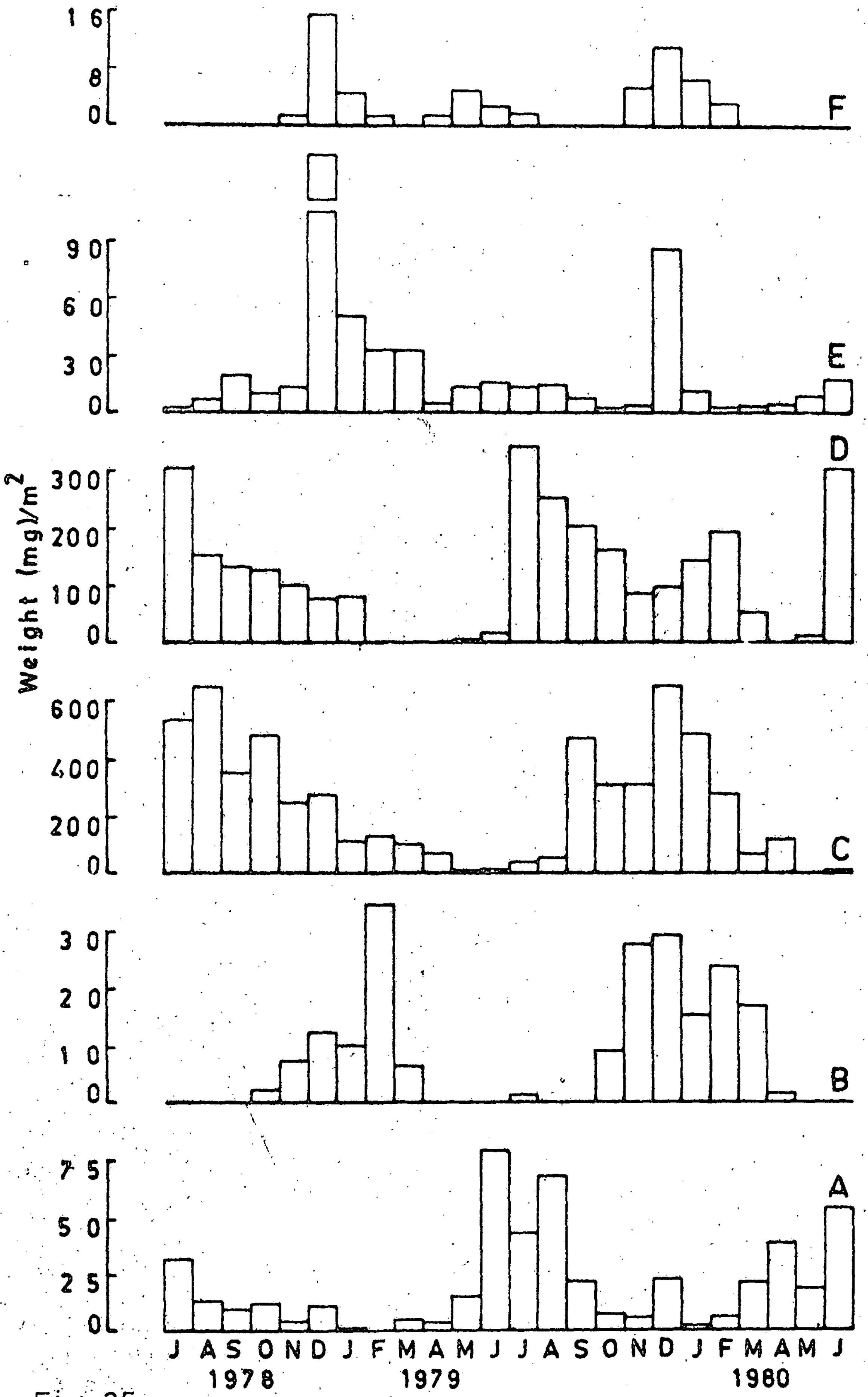
B - Caenidae

C - Libellulidae

D - Coenagrionidae

E - Chironomidae

F - Culicidae



16
8
0
F
90
60
30
0
E
300
200
100
0
D
Weight (mg)/m2
600
400
200
0
C
30
20
10
0
B
75
50
25
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig. 35

Figure 36 : Showing the density of various families of Coleoptera in terms of number/m^2 at Station 4 over the study period.

A - Dytiscidae

B - Hydrophilidae

C - Noteridae

D - Gyrinidae

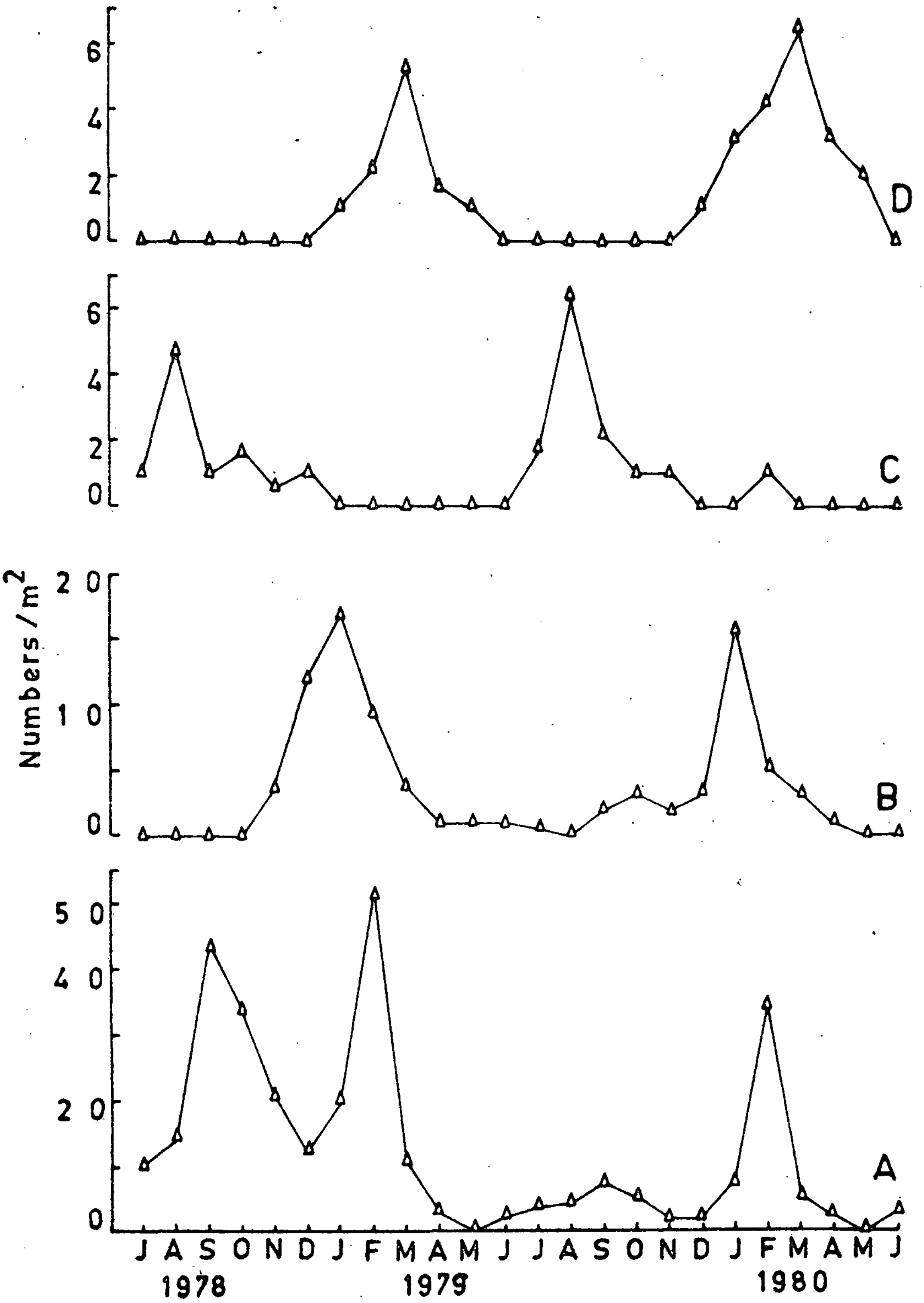

6
4
2
0
D
6
4
2
0
C
Numbers / m2
2 0
1 0
0
B
5 0
4 0
2 0
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980
Fig. 36

Figure 37 : Showing the biomass of various families of Coleoptera in terms of weight (mg)/m^2 at Station 4 over the study period.

A - Dytiscidae

B - Hydrophilidae

C - Noteridae

D - Gyrinidae

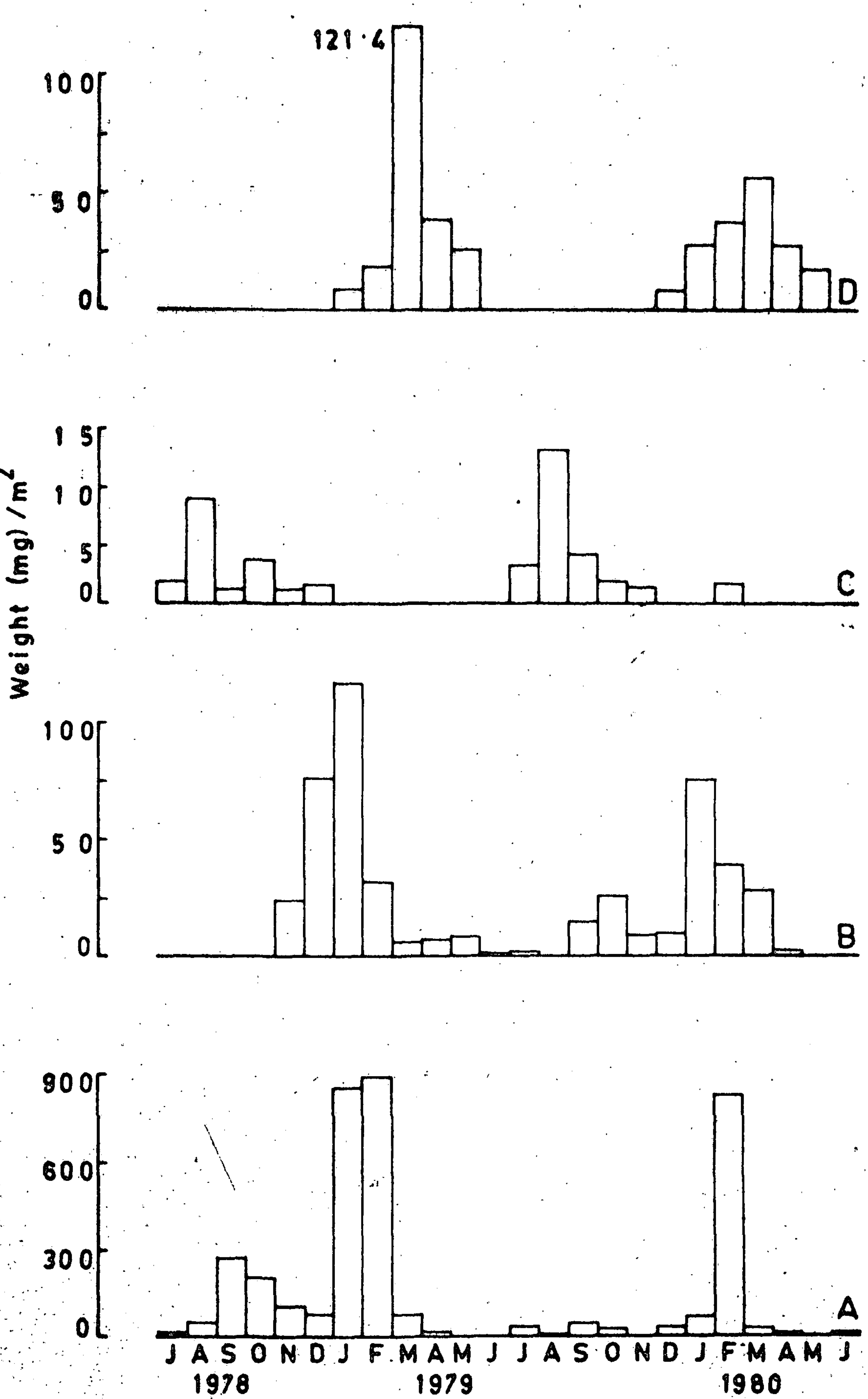

121·4
100
50
0
D
15
10
5
0
C
Weight (mg)/m²
100
50
0
B
900
600
300
0
A
J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980

Fig . 37

TABLE-5 : Showing the density (no/m^2) of various species of insects at Station 4 over the study period.

Insect species :

1. Anisops bouvieri Kirkaldy
2. Agraptocorixa hyalinipennis Fabr.
3. Micronecta sp.
4. Ranatra filiformis Fabr.
5. Laccotrephes grossus Fabr.
6. Plea areolata Paiva
7. Neogerris parvulus Stal
8. Diplonychus rusticus Fabr.
9. Cloeon sp.2
10. Caenis sp.
11. Orthetrum sp.
12. Unidentified Coenagrionidae
13. Laccophilus sindensis Vazirani
14. Laccophilus flexuosus Aube.
15. Hyphoporus elevatus Sharp.
16. Cybister sp.
17. Berosus fairmairei Zaitzev.
18. Berosus pulchellus W.M'Leay
19. Regimbartia attenuata (F)
20. Enochrus sp.
21. Canthydrus laetabilis (Walker)
22. Dineutus unidentatus Aube.
23. Chironomus sp.
24. Tanypus sp.
25. Unidentified Culicidae

TABLE-5

Insect species	1978						1979												1980					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1.	51.0	26.6	12.5	23.4	28.6	22.4	39.6	32.3	14.6	7.3	8.9	58.3	168.2	36.5	13.5	13.5	18.8	15.6	16.7	14.6	45.8	56.3	27.1	120.8
2.	4.2	14.1	17.7	13.0	18.9	25.0	15.1	10.4	4.2	1.6	5.2	9.4	43.2	12.5	4.2	6.3	10.4	5.2	3.1	1.0	6.3	2.1	11.5	14.6
3.	4.2	19.8	66.7	16.7	9.9	29.2	10.9	6.3	2.1	2.6	12.0	12.5	51.0	15.6	6.3	11.5	2.1	-	2.1	3.1	1.0	8.3	5.2	11.5
4.	2.1	5.2	1.0	2.1	1.0	0.5	0.5	1.0	-	-	-	1.6	5.2	1.0	2.1	2.1	1.0	-	-	-	-	-	-	-
5.	-	-	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	1.0	1.0	-	-	-	-	-
6.	-	3.6	-	-	-	1.0	2.6	15.6	5.7	3.1	-	-	-	-	-	-	-	-	2.1	3.1	17.7	2.1	-	-
7.	4.2	6.3	2.1	2.1	3.1	1.6	0.5	-	-	-	-	-	2.1	5.2	3.1	2.1	3.1	3.1	1.0	1.0	-	-	-	-
8.	2.1	5.7	2.1	1.0	-	-	-	-	-	-	1.0	2.6	6.3	2.1	1.0	-	-	-	-	-	-	-	-	-
9.	25.0	11.5	7.3	4.7	2.1	3.1	2.1	-	2.6	4.2	10.9	54.2	28.6	37.5	11.5	4.2	6.3	8.3	2.1	5.2	10.4	16.7	11.5	32.3
10.	-	-	-	1.6	6.3	8.9	7.3	25.0	4.7	-	-	-	1.0	-	-	4.2	20.8	27.1	7.3	11.5	9.4	2.1	-	-
11.	5.2	3.1	2.1	2.1	5.7	7.3	3.1	2.1	1.6	2.1	2.6	4.2	4.7	2.1	2.1	3.1	4.2	8.3	5.2	2.1	1.0	1.0	-	3.1
12.	25.0	18.7	13.5	9.3	6.8	4.2	2.6	-	-	-	7.8	17.2	27.6	34.4	26.1	17.7	10.4	8.3	7.3	10.4	2.1	1.0	11.5	26.0
13.	3.1	4.2	16.7	22.4	13.5	8.3	7.8	17.7	3.1	-	-	-	-	-	-	2.1	-	-	-	11.5	1.0	-	-	-
14.	7.3	9.9	27.1	11.5	7.3	4.2	9.4	30.2	5.2	2.6	-	2.1	3.6	4.2	7.3	3.1	2.1	-	4.2	20.8	4.2	2.1	-	3.1
15.	-	-	-	-	-	-	1.0	2.1	2.1	-	-	-	-	-	-	-	-	2.1	3.1	1.0	-	-	-	-
16.	-	-	-	-	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	-
17.	-	-	-	-	2.6	8.3	12.0	2.1	2.1	1.0	-	1.0	0.5	-	-	-	-	2.1	7.3	2.1	1.0	1.0	-	-
18.	-	-	-	-	1.0	2.1	2.1	4.2	-	-	-	-	-	-	-	-	-	-	4.2	2.1	2.1	-	-	-
19.	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	1.0	3.1	1.0	-	-	-	-	-	-	-
20.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	1.0	1.0	4.2	1.0	-	-	-	-
21.	1.0	4.7	1.0	1.6	0.5	1.0	-	-	-	-	-	-	1.6	6.3	2.1	1.0	1.0	-	-	1.0	-	-	-	-
22.	-	-	-	-	-	-	1.0	2.1	5.2	1.6	1.0	-	-	-	-	-	-	1.0	3.1	4.2	6.3	3.1	2.1	-
23.	3.1	10.9	14.6	4.7	10.4	93.7	23.4	10.4	19.7	5.7	12.5	14.6	8.3	10.4	4.2	4.2	5.2	69.8	9.4	3.1	7.3	5.2	7.3	20.8
24.	-	2.1	4.2	3.1	6.3	14.6	7.3	3.1	6.3	1.0	4.2	5.2	-	-	-	2.1	3.1	9.4	2.1	-	2.1	3.1	3.1	5.2
25.	-	-	-	-	2.1	5.7	1.0	1.0	-	1.0	5.2	1.6	0.5	-	-	-	3.1	6.3	2.1	1.0	-	-	-	-

numerous than Tanypus (14.6/m^2). The former was recorded throughout the study period, while the latter was absent during July '78, July to September '79 and February '80 (Table-5).

Culicidae showed very low density, ranging between 0.0 and 6.3/m^2 (Figure 34-F). Maximum values were recorded in December '78 (5.7/m^2) and May '79 (5.2/m^2) in the first cycle and December '79 (6.3/m^2) in the second cycle. The members of this family was collected during November '78 to February '79, April to July '79 and November '79 to February '80. The biomass indicated its maximum values in December (15.2 mg/m^2 and 10.8 mg/m^2) in both the annual cycles (Figure 35-F). The family was represented by larval stages which were not identified.

D I S C U S S I O N

The present investigation where population analysis of various aquatic insects in four fish ponds were conducted, it was observed that the maximum abundance of insect fauna occurring in such systems show more or less an increasing tendency as one goes from higher altitudes down to plains. At Station 1 and 3, it was nearly $430/m^2$ and $440/m^2$ respectively, while it was nearly $550/m^2$ at Station 4, revealing the increase in densities, with however the exception of Station 2, where the population density was lower than $200/m^2$. Interestingly enough, a trend in the reverse was observed for biomass for these same insects. Once again the exception was Station 2, where the biomass was a little less than 3000 mg/m^2. The increase of biomass from the plains to higher altitudes was seen, as more than 4000 mg/m^2, 5000 mg/m^2 and 6000 mg/m^2 at Stations 4, 3 and 1 respectively (Table-6). From these observations, one would like to conclude that the altitudes probably possess larger sized individuals, nevertheless with less numerical densities in contrast to the plains. Further, the species diversity at altitudinal gradients which is a function of adaptability, is a feature to be taken into account to explain such differences in number and sizes.

When the total insects were broken up into their respective orders, a similar pattern emerged for density alone in case of Hemiptera and Coleoptera. The other three orders viz., Ephemeroptera, Odonata and Diptera however, failed to reveal any such clear trend. A pattern similar to that of the total insects was also observed for biomass in Coleoptera.

TABLE-6 : Showing the maximum occurrence of insects in terms of density (no./m^2) and biomass (mg/m^2) at Stations 1,2,3 and 4.

TABLE-6

	Station-1 (Fish Dale, Shillong)	Station-2 (Mawpun Fish Pond)	Station-3 (Kyrdemkulai Fish Pond)	Station-4 (Ulubari Fish Pond)
(A) Density (No./m^2)	428.9	182.8	436.9	543.2
(B) Biomass (mg/m2)	6083.6	2637.3	5221.0	4133.9

When the seasonality of the entire groups of insects was observed, irrespective of the altitude at which these fish ponds were situated, most of the time the maximum numbers occurred in autumn or early winter, while the minimum was seen in spring or summer. However, when viewed as specific groups, Hemiptera, Ephemeroptera and Odonata show their maximum shift to the summer months as observed at Station 4, which is located at the plains or foot-hills. Of these, the regularity of the seasonal occurrence of the order Hemiptera was exemplified always by a peak in late summer or autumn and the least abundance in spring.

It is increasingly realised in recent years that the aquatic bugs which make up the order Hemiptera, are recognised to be the major component of the freshwater community food-webs. Hence their life-cycle pattern and the seasonal abundance decidedly synchronise not only with the season but also with the higher and lower trophic levels in a given pattern of food-chain. In addition, among the complex abiotic factors governing the seasonal variations of aquatic bugs, generally temperature and rainfall are known to have considerable influence. However, reports both in support and against this viewpoint exist for fish ponds in India. In his studies of a perennial fish pond in West Bengal area, Julka (1977) observed that the important genera of the bug population, such as Anisops, Micronecta and Plea are abundant during the months when temperature and rainfall are maximum. Tonapi (1959) also pointed out that temperature and rainfall have an augmentative effect on the fluctuations in the population of these insects. In contrast, a recent study revealed a higher density of the total population of aquatic bug Diplonychus indicus in August, October and December (Venkatesan, 1981). It was observed that during these months, the ionic content and temperature were correspondingly low, when the population was abundant and in summer, both these hydrological features were at their maximum when the population decreased. In the present study, the period of maximum abundance of Hemiptera roughly corresponds to monsoon or post-monsoon months. Thus a build-up in population was mostly preceded by heavy rains. The capacity of the bugs to migrate appears to be another important factor causing fluctuations in their populations. It was seen that peak in adult population is followed by an immediate decline, caused by immigration, probably due to crowding (Julka, 1977). Hutchinson (1933) also observed that local migration plays a prominent role in the bionomics of many species of Notonectidae and Corixidae. Fernando (1960) recorded aquatic insects migrating during the monsoons in Sri Lanka. In the present investigations a few species of bug population such as *Anisops* sp., *Micronecta* sp. and *Agraptocorixa hyalinipennis* were caught at light in Station 1 during monsoons (vide Chapter II) indicating that migration could have regulated the seasonal abundance. It may however be safe to conclude that the rainfall seems to be the triggering mechanism for the build up of population of these aquatic bugs.

As regards the different families under Hemiptera, i.e. Notonectidae, Corixidae, Gerridae and Belostomatidae mostly revealed an autumn or winter maxima and a summer or spring minima in Stations 1 to 3. These families however revealed a summer maxima and a spring minima at Station 4. This difference in seasonality may be due to the altitudinal variation, as Station 4 is situated in the foothills. Corixidae, more than any other family of Hemiptera, is known to prefer a muddy substratum as one of the chief characteristics of their habitat. This was shown to be true of temporary ponds and canals (in very large numbers) where the water was turbid and muddy and their numbers large (Tonapi, 1959). In the present study, the highest abundance of Corixidae was recorded in Station 4, which had a similar substratum. A spring and winter minima was seen for family Nepidae in Station 1. Although it recorded autumn maxima in Stations 2 and 3 and summer maxima in Station 4, generally the family was conspicuous by its absence during several months in these three stations. As a group, the members of this family showed consistency in recording low values in all the stations. Family Pleidae which was collected only in Station 4, revealed a spring maxima and moreover its presence was limited to a few months during both the annual cycles

The population trend of Ephemeroptera also showed altitudinal variations. A winter maxima and summer minima was revealed at Stations 1 and 2, while a summer maxima and an autumn or spring minima was observed in Stations 3 and 4. Macan (1962) suggested that temperature is one of the factors that determines the population distribution of Ephemeroptera. It is well known that temperature may influence the distribution of freshwater organisms in one of the two main ways; either temperature may be lethal to a certain stage in the life cycle, or growth rate of the animal may be affected, such that its life cycle is not synchronised with other environmental parameters. Obviously, these two are linked in many situations. Kjellberg (1973) observed that the best growth of 3 species of Ephemeroptera (Leptophlebia vespertina, Cloeon dipterum and Ephemera vulgata) occurred under conditions of abundant food and high temperatures. Brittain (1974) recorded good correlation between the number of Ephemeroptera species and the duration of ice-free period (r=0.88), indicating the importance of temperature and possibly also the length of the period of autophthonus primary production. In a study of the emergence patterns of Baetis vernus, Illies and Masteller (1977) postulated that warm overwintering temperatures produce unimodal emergence whereas cold winter temperatures produce bimodal or trimodal emergence. In the present study there was a decrease in the magnitude of temperature, with increasing altitude. Thus, Station 1 (located at the highest altitude) recorded the lowest maximum and minimum temperatures (both air and water). It is interesting to note that at this Station 1, a record of the highest abundance of Ephemeroptera was observed. It seems, therefore, probable that the variation in the seasonal fluctuations of Ephemeroptera at different altitude as shown by the present studies too is determined by variations in temperature. As seen in Stations 1 and 2, a winter maxima and a summer minima was also recorded by Craven and Brown (1969) for Hexagenia naiads in an Oklahoma reservoir. However, it is admitted that other abiotic and biotic factors may also influence Ephemeropteran population. Studies on the biology of Ephemerella funeralis by Fiance (1978) revealed that the species tend to decrease in abundance with decreasing stream pH and decreasing organic matter. Petr (1970) suggested that the abundance of Povilla nymphs seems to depend on the type of substrate. They preferred the soft wood trees. Brittain (1978) observed that detritus was a significant factor in explaining the variation in total Ephemeropteran numbers around the lake Ovre Heimdalsvatn. In the present investigation, it was seen that the amount of detritus was maximum in Stations 1 and 3, followed by that of

Station 4. It was very less in Station 2, which incidently recorded the lowest maximum abundance. Apart from the factors mentioned above, probably, life cycle periodicity was also responsible for the seasonal fluctuations of Ephemeroptera as pointed out by Gupta (1980).

Baetidae being the dominant family, indicated the same pattern of seasonality as recorded in the order Ephemeroptera. Family Caenidae was recorded only in Stations 2 and 4 and it showed early winter or mid winter maxima. This family was totally absent during spring months in Station 2 and during summer and autumn in Station 4. Bradbeer and Savage (1980) recorded Caenis robusta in only 8 of 107 water bodies they had sampled. The common feature of the 8 habitats were that they contained plant debris, waters were still or slow flowing and had conductivities ranging from 120-687 μhos/cm at 25°C. In the present study, the presence of Caenidae in Station 4 is understandable, as it contained large amounts of plant debris. However, its presence in Station 2 is difficult to explain.

The order Odonata had its peaks during summer or late summer months in all the stations except 3, where it was recorded during late autumn or early winter months. However, all the stations recorded a spring or late-spring minimum. Studies on the dragonfly population of a farm pond by Benke and Benke (1975) revealed that the highest densities occurred in midsummer while the lowest densities were observed in midspring. It was also indicated that the similarity in density trend for all 4 years was consistent. In the present study, the seasonality in density fluctuations also showed consistency for both the annual cycles.

Ball and Hayne (1952) and Lawton (1970) reported densities of Zygoptera in the hundreds/m^2, and Macan (1964) found Pyrrhosoma densities as high as 1,400/m^2. Dineen (1953) reported a total Anisopteran density of only 10/m^2, although others frequently found densities of 100/m^2 or more (Ball and Hayne, 1952; Beatty and Hooper, 1958; Gerking, 1962). Benke (1975) recorded the highest density of over 1,700/m^2 for total Odonates. In the present study, the highest density of 182/m^2 for total Odonate was observed in Station 3, where it represented as the predominant group. The other stations showed comparatively low density. However, quantitative field data necessary for understanding Odonate population dynamics are scarce (Lawton, 1970). Gower and Kormondy (1963) in their studies on the life-history of Lestes rectangularis indicated that for successful larval development, the suitable habitat is a shallow pond, characterized by a high total alkalinity, dense growth of emergent and submerged vegetation, and a bottom rich in organic ooze. Kharitnov (1976) found that living conditions best suited for dragonfly larvae in Arctic regions are: waters to be situated in low lying areas, overgrowth of shores by thickets of dwarf birch and polar willows. Benke (1975) indicated that the dramatic increase in population (from 1968-1969) of several species of Odonata was probably due to the increase in macrophytes. Among the stations studied during the present investigation, Station 3 was most abundant in submerged and emergent vegetation. It is worth mentioning that Station 2 which represented the lowest abundance of Odonates was also meagre in vegetation. Thus aquatic vegetation may be one major factor which influences the abundance of Odonata. Recently, Kumar (1978) also observed that presence or absence of a particular type of shore vegetation may be an important factor in the habitat preference, especially in those species which oviposit endophytically or have their larvae living amidst the upright vegetation. Another important factor to be mentioned is availability of food. Corbet (1957) indicated that some changes in larval distribution may be related to food supply, larvae moving from areas of low to areas of high prey density. Petr (1968) observed that population density probably have been affected both by the suitability and availability of prey and by the activity of the predators. Although the temporal separation among genera occurring in similar microhabitat may function in relieving potential competitive pressure (Benke, 1970), intense interspecific interactions are possible, as indicated by Benke and Benke (1975). Thus the larger animals may prey on the smaller animals. In the present study, cannibalism was noticed among Anisoptera on several sampling dates in Station 3.

The Odonata families - Libellulidae and Coenagrionidae mostly revealed an autumn or winter maxima and summer minima. Family Aeshnidae was recorded only in Stations 1 and 3, while Lestidae was observed only in Stations 2 and 3. Although both the families mostly showed a summer or autumn maxima, they were irregular in their occurrences, being absent during many months.

The population of Coleoptera mostly showed an early spring maxima in all the stations except 2, where a summer and autumn maxima was observed. Moreover, stations 3 and 4 recorded a second pulse during summer and autumn respectively. The minimum abundance was observed in winter or autumn months in stations 1 to 3 and in late spring in station 4. Information in the literature indicates that water beetles in general are univoltine. Usually they breed in spring and summer and adults hibernate in winter (Leech and Chandler, 1956). The pattern of fluctuations during the present investigation fits an univoltine life-cycle. Similar patterns of seasonal abundance was recorded by Zimmerman (1960) for Dytiscid beetles. As shown by Zimmerman (1960) during early spring, numbers increased rapidly to a maximum due to renewed activity of overwintering individuals. The numbers declined to a minimum as the overwintered generation died. During summer, numbers rose again and many of the beetles were newly emerged and immature. A new peak was reached in autumn before imagines disappeared for hibernation. A similar pattern was observed in the present studies also. Further, Landin (1976) found that in Swedish ponds, Hydrophilids were at maximal abundance during spring, minimal during summer and sometimes a smaller peak during late summer and autumn. Zalom _et al_ (1980a) also observed that Hydrophilids in California rice fields exhibited similar patterns. Thus, it is evident that the pattern of seasonality of Coleoptera recorded during the present investigations showed a very close similarity to the studies mentioned above. It is to be noted that dispersal which is of common occurrence to a number of aquatic beetles, also influences the life-history patterns. The dispersal provides the basis for colonization or establishment of the animal in a suitable habitat. With this process aquatic insects are able to utilize small and often temporary habitats as feeding and breeding grounds. It was observed that peak in abundance of some insects coincides with its dispersal phase (Fernando, 1958; Landin and Stark, 1973). In the present investigation, at Station 1, where the dispersal was studied with light-traps, no such coincidence was observed (vide Chapter II). Another factor which also influence the life-history pattern is climate. Landin (1976) indicated that low abundance of Hydrophilidae beetle was possibly due to long winter, causing a large mortality among hibernating specimens. Zimmerman (1960) observed that factors which seem to have an effect on the abundance of beetles are temperature, amount of vegetation, shading of water surface, shore margin profiles and nature of the soil or soil forming materials adjacent to the water. It was reported that larvae of Desmopachria convexa were found in habitats supporting dense growths of aquatic vegetation (Berman, 1973). In the present study, the maximum abundance was seen in Station 4, followed by Stations 3 and 1, in that order. As mentioned earlier, the aquatic vegetation of Station 2 was very poor, and it recorded the lowest maximum values. Thus aquatic vegetation which provides the necessary shade and suitable substrates to these beetles, probably also influenced the abundance of the beetles during the present study.

Among the families of Coleoptera, Dytiscidae revealed consistency in mostly recording a spring or summer maxima. However, it was not consistent in their period of minimum values, which was seen in autumn at Stations 1 and 3, winter in Station 2, and early summer in Station 4. Family Hydrophilidae revealed maximal values in summer or autumn at Stations 1 to 3, but in winter in Station 4. Station 1 revealed a winter minima, while in the other three Stations the family was absent during several months in both the annual cycles. The occurrence of Noteridae was limited to Station 4 only, where it showed an autumn maxima. However, its presence was restricted to a few months in both years. Family Gyrinidae was totally absent in Station 1. At the other three stations, an autumn or spring maxima was observed for this family. The family showed irregularity in occurrence, with total absence during winter or summer months in all the stations. Among the four families, a predominance of Dytiscidae was observed in all the stations. Fernando (1961b) indicated that majority of Hydrophilids are vegetarians and they often reach enormous numbers in habitats rich in decaying organic matter. However, in the present study none of the stations had a large population of the family. The absence of Gyrinidae in Station 1 may be due to the presence of blanket of algae, since its growth seriously hinders their surfacing activity. Tonapi and Ozarkar (1970) also held a similar view.

The order Diptera revealed mostly an early winter and/or spring maxima in all the stations. Stations 1 and 3 showed a second pulse in autumn, while Station 2 recorded a similar minor pulse in summer. Minimum abundance was observed in summer in Stations 1, 3 and 4 and in autumn in Station 2. The differences in the seasonal fluctuations in different stations may be due to the difference in species composition. The numerical increase during spring and summer is understandable as it coincided with warmer air and water during these periods. The summer minima may be due to rainfall. This finds support in the studies of Ali _et al_ (1977) who observed that 2 to 3 cm or more of rainfall in an urban flood control channel in 24 hrs period drastically reduced the larval population of Chironomid fauna, but within 2-4 weeks, after a period of rainfall they greatly increased. Matheny and Heinrich (1970) also showed that Chaoboridae and Chironomidae exhibited distinct seasonal variations in numbers, with the population decreasing throughout the summer. However, the early winter maxima in Stations 1 and 4 cannot be explained in the same way. It may be mentioned that Station 4 recorded the highest abundance, followed by Station 1. The other two Stations (2 and 3) recorded much lower abundance. Petr (1974) observed that density of Chironomidae was largely determined by the presence of suitable substratum. The larvae used fine mud particles for the construction of the tubes which they inhabit. Armitage (1970) indicated that differences in population density of larvae from two stations may have been due to differences in the richness of mud or possibly to wind effect. It was also pointed out that benthos recolonised more rapidly and was of greater density in substrates containing large amounts of detritus or organic matter (Kaster and Jacobi, 1978). In an earlier study, Ravera (1966) also indicated that detritus rich in organic matter which can provide a continuous supply of food would support a high density of benthic organisms. Thus, it is obvious that Stations 1 and 4, having a muddy bottom and sufficient amount of detritus would have a higher share of benthic dipteran organisms.

Family Chironomidae of order Diptera mostly had a winter maxima and a summer minima for all the stations except 2, where the pattern was in the reverse. The family Culicidae indicated its peaks mostly during spring months in Stations 1 to 3, and during winter in Station 4. No clear pattern emerged for the minimum values. This may again be probably due to the differences in the species composition at different stations.

The trend of fluctuations in biomass, although generally followed a similar pattern as density, there were occasional shifts in peaks in some groups. The peak in biomass in Hemiptera mostly followed the same trend as density with a summer or autumn peak and spring minimum. In Station 2, the peak in biomass was dèffered by a month in the first cycle. The Ephemeropteran biomass followed the same trend as density in Stations 2, 3 and 4. However, in Station 1, the peak in biomass was much above that of density. The order Odonata followed more or less the same trend as density in Stations 1 and 2. The peak value showed shifts in Stations 3 and 4. In both the stations, the peak was delayed by a few months. Coleoptera indicated a trend in biomass almost similar to density in Stations 1 and 4. The maximum was delayed by a month in the first cycle in Station 2 and in the second cycle in station 3. In Station 3, the peak density in the first cycle did not show a corresponding peak in biomass. The pattern of biomass fluctuations in Diptera followed more or less the same trend as density, although there was a minor shift in Stations 2 and 3. It may be pointed out that peak in abundance of relatively low biomass indicates the occurrence of young nymphs (Petr, 1968). In such cases, the peak may be delayed and it appeared only when the nymphs were large, accounting for the discrepancy of density and biomass peaks.

As regards families, all the families of Hemiptera, except Nepidae showed more or less the same trend as density, although there was occasional shifts in peak values. Nepidae showed trends in biomass different from density in Stations 1 and 4. This was due to the irregular occurrence of heavier species like *Laccotrephes grossus*. Except for Station 1, families Baetidae and Caenidae showed trends identical to density. In Station 1, the peak in biomass was much above density. The families of Odonata recorded trend in biomass similar to density except for some minor shifts. In case of both Coleoptera and Diptera, the biomass mostly revealed patterns similar to density.

In general, it can be said that although the trend in biomass almost followed the pattern of density, in some cases the peak in biomass did not reflect the corresponding density peaks. It was seen to be either ahead of density peaks or delayed by a few months, as seen in some groups.

A look into the species composition of the insect fauna in the four stations revealed that altogether 44 species were represented. However, the four stations did not reflect much difference in the total numbers of insect species, with Station 4 recording the highest number of 26 species, followed by Station 3 (24), 2 and 1 (both 22). Among the various orders, Coleoptera showed the highest number of 17 species, followed by Hemiptera (13), Diptera (6), Odonata (5) and Ephemeroptera (3).

An analysis of the physico-chemical factors of the four stations revealed that air and water temperatures recorded a consistent summer maxima and a winter minima in all the stations. Of the several factors which together constitute what is called climate, the one with the most direct ecological effect is temperature (Boughey, 1971). It is common knowledge that in freshwater environments temperature is also the main variant which influences the biota (Macan, 1961, 1963; Martin, 1972). The record of summer maxima and winter minima is in general agreement with tropical aquatic systems as observed by many workers such as Michael (1964), Rao and Govind (1964), Hussainy (1967), Mukherjee and Moitra (1972). Free carbon-dioxide showed mostly a summer or spring maxima and a winter minima for Stations 1, 2 and 4. Station 3 revealed an autumn or winter maxima and summer minima. Free carbon-dioxide in water serves to "buffer the environment against rapid shifts in acidity-alkalinity states (Reid, 1961). In natural water, carbon dioxide is derived from atmosphere, bacterial decomposition of organic matter, respiration of plants and animals and inflowing rain water washing the decomposing top soil. An inverse relationship between dissolved oxygen and free carbon-dioxide has been indicated by Rao (1955), Sreenivasan (1965, 1970), Mandal and Hakim (1975) and Khan et al (1978). In the present study a more or less inverse relationship was observed in Stations 2 and 3. On the other hand a direct relationship was observed in Stations 1 and 4. As regards alkalinity, all the stations mostly revealed a spring maxima. However, Stations 1 and 2 showed a winter minima, while Stations 3 and 4 indicated a summer minima. It may be pointed out that in all the four stations the total alkalinity was due to bicarbonate only. It is known that a decrease in water level due to evaporation can cause steady increase in alkalinity (Hazelwood and Parker, 1961; Michael, 1964). In the present study no such influence of water level was studied. It was observed that in Stations 2 and 3, when the dissolved oxygen content was high, the amount of bicarbonate was low and vice-versa. Ganapati (1943) also reported similar relationship. The pH was in the acidic range in all the stations except 4, which was in the alkaline range. Maximum values in Stations 1 and 2 was observed during summer, while in Stations 3 and 4, the same was revealed in spring. The fall in pH values was seen during winter in Stations 1 and 3, while it was seen during autumn in Stations 2 and 4. The increase of pH during hotter months may be due to high photosynthetic activity in the pond (Verduin, 1960) and the decrease during certain months may be due to the decomposition of vegetation, thereby increasing bicarbonates (Rao, 1962). Dissolved oxygen recorded maximum mostly during summer or autumn months and minimum during spring or winter months in all the stations. It is well known that dissolved oxygen content of any aquatic system is influenced by a number of environmental factors (Ganapati, 1940). As in pH, the high values of oxygen during warmer months may be attributed to the photosynthetic activities of the rooted plants which grows profusely during the rainy season. Ganapati (1941, 1943) also recorded increased dissolved oxygen during the summer months.

For a knowledge of the basic idea of the dynamics of populations of these aquatic insects seasonally, along with the abiotic environmental parameters and their rythmicity, it was felt to observe whether any intricate relationship existed between these two oscillating mechanisms. Such a relationship would possibly indicate the presence of either density independent or density dependent attributes. Though the latter is not possible to elucidate in the present investigation, the former could at least play a part in finding the role of extrinsic factors on such patterns of insect population fluctuations.

Therefore, a statistical co-efficient correlation was made between the environmental factors undertaken and the various orders of insect groups. A perusal of the Tables 7,8,9 & 10, indicate that the orders Ephemeroptera and Diptera at Station 1, which is situated at the highest altitude, revealed significant negative relationship with air-temperature, water temperature, pH and free carbon-dioxide. The first three variables except for Ephemeroptera, are highly significant at .01 level, while carbon-dioxide at .05 level. In addition, at Station 1, Hemiptera showed a highly significant relationship though negatively, with pH ($P < .01$) and Ephemeroptera with alkalinity ($P < .05$). The other orders Odonata and Coleoptera did not reveal any relationship with any factors at this station.

Hemiptera and Odonata showed a significant negative relationship with alkalinity at Station 2, though the former was highly significant. Further, Ephemeroptera showed significant negative relationships with air-temperature, water temperature and carbon-dioxide, with the former at $P < .01$ level and others at $P < .05$ level. Odonata similarly at Station 2, showed significant negative relationship, but only with CO_2. Interestingly enough, the order Coleoptera showed positive significant relationship with air and water temperature, both at $P < .01$ level. Order Diptera did not show any relationship with any factors in this station.

At Station 3, Hemiptera and Ephemeroptera did not have any relationship, while Odonata was highly significant ($P < .01$) though negatively with air and water temperature and positively with CO_2. Coleoptera was seen to have positive correlations with pH, while Diptera with air-temperature negatively, both however at $P < .05$ level.

In Station 4, only Odonata and Coleoptera revealed relationships. Interestingly enough for those factors where they showed such statistical correlations, invariably they were in the reverse order. Thus air and water temperatures were positively significant for Odonata but were negative for Coleoptera and were again highly significant in the latter. In addition, Coleoptera revealed relationships with pH and dissolved oxygen, both at

$P < .05$ level. Once again it is only at this station and with only Coleoptera that dissolved oxygen showed a relation. Odonata and Coleoptera also showed a relation with alkalinity, the former negatively at $P < .05$ level and the latter positively at $P < .01$ level.

After the attempt to directly correlate the individual abiotic factors and the orders of insects, a multiple correlation analysis was performed to see whether there was any significance of correlation of all these abiotic factors for the order concerned, independent of whether individual factors were related or not. The order Hemiptera revealed highly significant relationships at Stations 1 and 2 only and no relationship at all in the remaining stations. Similarly, Ephemeroptera too had such a relationship at Stations 1 and 2 except that the former was not significant. The order Odonata was the only group which showed highly positive correlation at all the stations. Coleoptera showed positive significant correlation ($P < .01$ level) only at Stations 2 and 4, while Diptera, showed positive correlation at $P < .05$ level only at Stations 1 and 2.

TABLE-7 : Showing the Co-efficient correlation and multiple correlation between the orders of insects and the abiotic factors at Station 1.

TABLE-7

Orders	Co-efficient correlations						Multiple correla-tions
	Air Temp.	Water Temp.	pH	Free CO_2	Alkali-nity	Dissol-ved O_2	
Hemiptera	(-)0.271	(-)0.267	(-)0.663**	(-)0.367	(-)0.136	0.220	0.691
Ephemeroptera	(-)0.561*	(-)0.599**	(-)0.706**	(-)0.533*	(-)0.527*	(-)0.082	0.531*
Odonata	(-)0.110	(-)0.109	(-)0.493	(-)0.302	(-)0.102	0.360	0.544**
Coleoptera	(-)0.0149	(-)0.0481	(-)0.0311	(-)0.0320	0.0950	(-)0.395	0.0
Diptera	(-)0.641**	(-)0.646**	(-)0.644**	(-)0.523*	(-)0.356	(-)0.243	0.530*

* = $P < 0.05$
** = $P < 0.01$

TABLE-8 : Showing the Co-efficient correlation and multiple correlation between the orders of insects and the abiotic factors at Station 2.

TABLE-8

Orders	Co-efficient correlations						Multiple correla-tion
	Air Temp.	Water Temp.	pH	Free CO_2	Alkali-nity	Dissol-ved O_2	
Hemiptera	0.275	0.269	(-)0.320	(-)0.330	(-)0.608**	0.305	0.738**
Ephemeroptera	(-)0.536**	(-)0.497*	0.0842	(-)0.411*	(-)0.321	0.339	0.687**
Odonata	0.350	0.291	(-)0.329	(-)0.464*	(-)0.414*	0.319	0.642**
Coleoptera	0.673**	0.697**	0.184	(-)0.172	(-)0.0073	0.168	0.721**
Diptera	(-)0.387	(-)0.361	0.309	(-)0.0776	0.358	0.181	0.483*

* = $P \leqslant 0.05$
** = $P \leqslant 0.01$

TABLE-9 : Showing the Co-efficient correlation and multiple correlation between the orders of insects and the abiotic factors at Station 3.

TABLE-9

Orders	Co-efficient correlations						Multiple correlations
	Air Temp.	Water Temp.	pH	Free CO_2	Alkalinity	Dissolved O_2	
Hemiptera	0.160	0.250	0.079	0.206	(-)0.328	0.243	0.229
Ephemeroptera	(-)0.121	(-)0.0431	0.105	0.0426	(-)0.0736	0.213	0.0
Odonata	(-)0.762**	(-)0.768**	(-)0.350	0.699**	0.392	(-)0.304	0.863**
Coleoptera	0.0571	0.116	0.410*	(-)0.373	0.158	(-)0.338	0.397
Diptera	(-)0.428*	(-)0.395	0.0731	0.0432	0.359	(-)0.401	0.185

* = $P \leqslant 0.05$

** = $P \leqslant 0.01$

TABLE-10 : Showing the Co-efficient correlation and multiple correlation between the orders of insects and the abiotic factors at Station 4.

TABLE-10

Orders	Co-efficient correlations						Multiple correla-tions
	Air Temp.	Water Temp.	pH	Free CO_2	Alkali-nity	Dissol-ved O_2	
Hemiptera	0.348	0.347	0.0704	0.138	(-)0.166	(-)0.0574	0.0
Ephemeroptera	0.282	0.277	0.0947	0.0544	(-)0.144	(-)0.0015	0.0
Odonata	0.464*	0.525**	(-)0.233	(-)0.176	(-)0.475*	(-)0.353	0.697**
Coleoptera	(-)0.659**	(-)0.589**	(-)0.473*	(-)0.0626	0.619**	(-)0.513*	0.753**
Diptera	(-)0.209	(-)0.288	(-)0.167	(-)0.279	0.0082	(-)0.082	0.195

* = $P < 0.05$
** = $P < 0.01$

CHAPTER - II

L I G H T-T R A P   S T U D I E S

RESULTS

During a period of 10 months starting from March '78 to December '78, light traps were set up at Fish Dale, Shillong to capture aquatic insects especially those belonging to the orders Hemiptera and Coleoptera.

Altogether 1077 insects belonging to both these orders were attracted to the traps. Hemiptera accounted for 670 individuals (62.2%), while Coleoptera contributed the remaining 407 individuals (37.8%) of the total insects caught.

A two-hourly analysis of the total insects and the individual orders of Hemiptera and Coleoptera during the study hours (1800 to 0600 Hrs), revealed that the maximum catch was recorded at 2000-2200 Hrs and 2200-2400 Hrs with 330 individuals (30.6%) and 300 individuals (27.9%) respectively. The minimum catch occurred at 0400-0600 Hrs with 56 individuals (5.2%). Hemiptera recorded a maximum of 219 individuals (32.7%) during 2000-2200 Hrs, while Coleoptera catch was maximum during 2200-2400 Hrs with 121 individuals (29.7%). Both the orders recorded their minimum catch during 0400-0600 Hrs with 34 (5.0%) individuals in the former and 22 (5.4%) individuals in the latter (Table-11).

It was seen that the monthly catch of total insects was highest in the month of August with 245 individuals, representing the peak of dispersal. A second pulse also was indicated in November with 129 individuals. The lowest catch during the entire period of study was seen in March (43 individuals) (Figure 38-A). It was revealed that of the two orders, Hemiptera catch was alway

TABLE-11 : Showing the two hourly analysis of the total insects and insect orders- Hemiptera and Coleoptera, caught in light-trap during 1800-0600 Hrs. over the study period (the figure in the parenthesis represents the percentage).

TABLE-11

Insect Orders	1800-2000 Hrs	2000-2200 Hrs	2200-2400 Hrs	2400-0200 Hrs	0200-0400 Hrs	0400-0600 Hrs	Total
Hemiptera	108(16.1)	219(32.7)	179(26.7)	73(10.9)	57(8.5)	34(5.0)	670(62.2)
Coleoptera	66(16.2)	111(27.3)	121(29.7)	54(13.3)	33(8.1)	22(5.4)	407(37.8)
Total Insects	174(16.2)	330(30.6)	300(27.9)	127(11.8)	90(8.3)	56(5.2)	1077

Figure 38 : A - Showing the seasonal fluctuations of total insect fauna and orders Hemiptera and Coleoptera caught in light-trap.

- ▯ Total Insects
- o——o Hemiptera
- o- - -o Coleoptera

B - Showing the seasonal fluctuations of various families of Hemiptera and Coleoptera caught in light-trap.

- o- · -o Notonectidae
- o- - -o Corixidae
- □- - -□ Gerridae
- o——o Dytiscidae
- △——△ Hydrophilidae

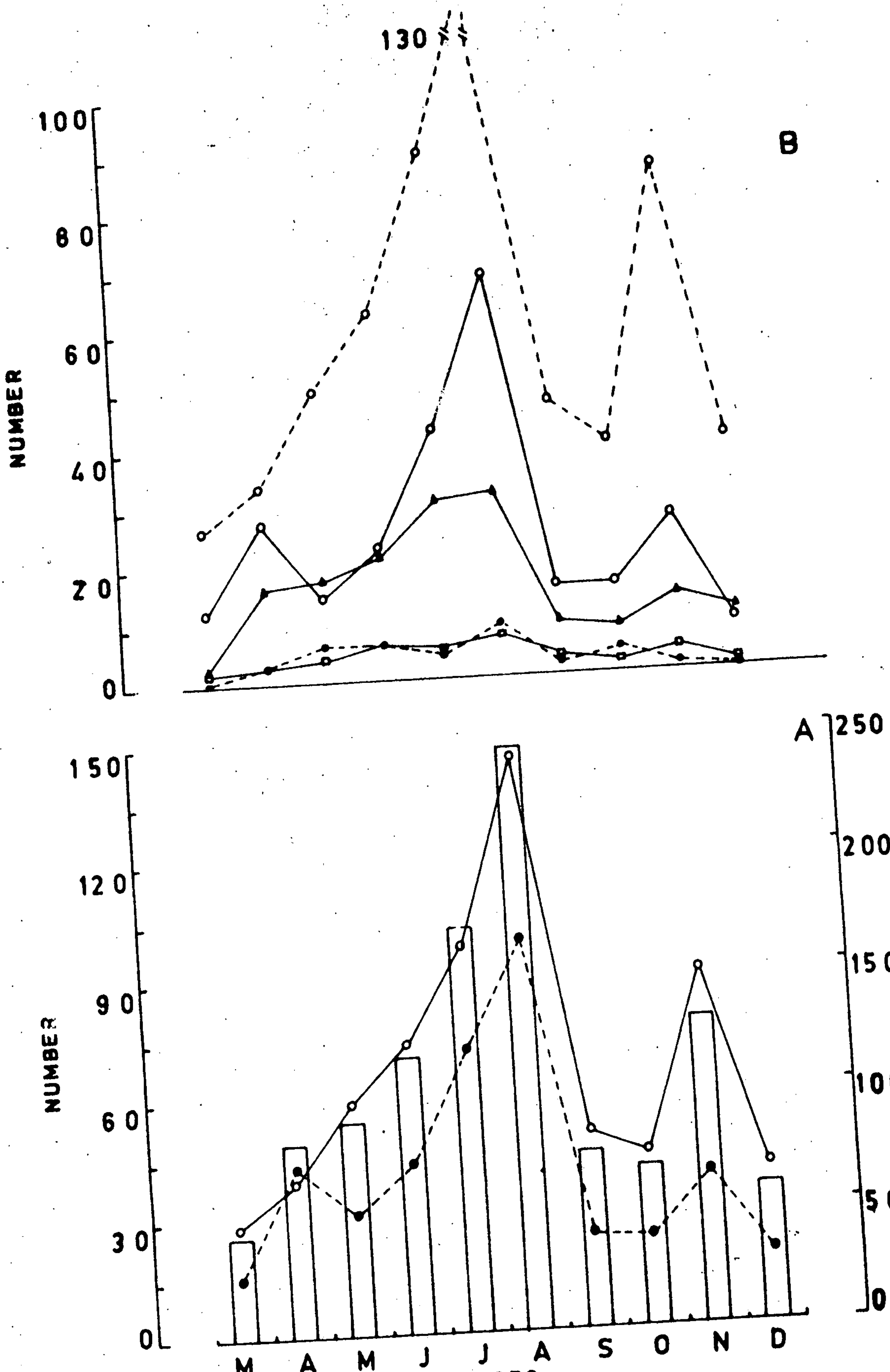


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Fig. 38

higher than that of Coleoptera except for the month of April, when the latter outnumbers the former by a small margin.

Hemiptera :

From March onwards, Hemiptera showed a steady rise and reached its peak of maximum increase in August with 146 individuals which accounted for 59.6% of the total catch for the month. The peak was followed by a steep fall in September which further decreased in October, after which the value rose to indicate a smaller pulse in November with 90 individuals (69.8%). December again showed a rapid decrease (Figure 38-A).

A two hourly analysis of the total insects of the two orders of aquatic insects during different months (from March to December '78) is presented in Table-12. Hemiptera recorded the maximum two hourly catch at 2000-2200 Hrs during the entire period of investigation, except for March and November when the maximum values were seen at 2200-2400 Hrs. The highest two hourly catch was observed in August at 2000-2200 Hrs with 54 individuals accounting for 22% of the total catch for the month. However, the highest percentage composition of 27.6% was revealed in December at 2000-2200 Hrs with 16 individuals. No Hemiptera was collected at 0400-0600 Hrs in March and at 0200-0400 Hrs in April. During the remainder of the study period (from May to December), the minimum two hourly catch was recorded at 0400-0600 Hrs, except for July, when the same was observed at 0200-0400 Hrs.

Hemiptera catch comprised of three families : Notonectidae, Corixidae and Gerridae.

Family Notonectidae showed fluctuations between 0 and 9

TABLE-12 : Density of insect orders- Hemiptera and Coleoptera caught in light-trap, over the study period (the figure in the parenthesis represents the percentage).

TABLE-12

Months 1978	Insect Order	1800-2000 Hrs	2000-2200 Hrs	2200-2400 Hrs	2400-0200 Hrs	0200-0400 Hrs	0400-0600 Hrs	Total
Mar.	Hemiptera	4(9.3)	7(16.3)	10(23.3)	3(7.0)	4(9.3)	0	28(65.1)
	Coleoptera	3(7.0)	4(9.3)	2(4.7)	3(7.0)	1(2.3)	2(4.7)	15(43.9)
Apr.	Hemiptera	7(8.5)	13(15.8)	10(12.2)	4(4.9)	0	5(6.1)	39(47.6)
	Coleoptera	8(9.7)	9(10.9)	12(14.6)	4(4.9)	6(7.3)	4(4.9)	43(52.4)
May	Hemiptera	12(13.3)	20(22.2)	16(17.8)	6(6.7)	3(3.3)	2(2.2)	59(65.6)
	Coleoptera	7(7.8)	5(5.6)	10(11.1)	3(3.3)	4(4.4)	2(2.2)	31(34.4)
Jun.	Hemiptera	15(12.8)	22(18.8)	16(13.7)	6(5.1)	12(10.3)	3(2.6)	74(63.2)
	Coleoptera	7(6.0)	10(8.5)	15(12.8)	4(3.4)	5(4.3)	2(1.7)	43(36.8)
Jul.	Hemiptera	17(10.0)	29(17.0)	28(16.5)	11(6.5)	6(3.5)	7(5.1)	98(57.6)
	Coleoptera	11(6.5)	16(9.4)	19(11.2)	18(10.6)	4(2.4)	4(2.4)	72(42.4)
Aug.	Hemiptera	20(8.2)	54(22.0)	40(16.3)	17(6.9)	8(3.3)	7(2.9)	146(59.6)
	Coleoptera	13(5.3)	32(13.1)	35(14.3)	10(4.1)	5(2.0)	4(1.6)	99(40.4)
Sep.	Hemiptera	9(12.0)	18(24.0)	8(10.7)	8(10.7)	6(8.0)	2(2.7)	51(68.0)
	Coleoptera	3(4.0)	10(13.3)	3(4.0)	6(8.0)	2(2.7)	0	24(32.0)
Oct.	Hemiptera	7(10.2)	18(26.5)	11(16.2)	4(5.9)	4(5.9)	1(1.5)	45(66.2)
	Coleoptera	5(7.3)	7(10.3)	8(11.8)	1(1.5)	2(2.9)	0	23(33.8)
Nov.	Hemiptera	11(8.5)	22(17.0)	32(24.8)	11(8.5)	9(7.0)	5(3.9)	90(69.8)
	Coleoptera	7(5.4)	10(7.8)	13(10.1)	3(2.3)	4(3.1)	2(1.6)	39(30.2)
Dec.	Hemiptera	6(10.3)	16(27.6)	8(13.8)	3(5.2)	5(8.6)	2(3.4)	40(69.0)
	Coleoptera	2(3.4)	8(13.8)	4(6.9)	2(3.4)	0	2(3.4)	18(31.0)

individuals (Figure 38-B). The maximum catch was obtained in August. No individuals of the family was recorded during March and December. The family was represented by Anisops sp.(Figure 39-A).

Corixidae was most abundant of the three families. It indicated the same trend of fluctuations as Hemiptera. The maximum catch was recorded in August with 130 individuals (Figure 38-B). A second peak was indicated in November with 85 individuals. Lowest catch was seen in March with 26 individuals. Corixidae had two representatives: Micronecta sp. and Agraptocorixa hyalinipennis. Both the species indicated the same trend of fluctuations as family Corixidae (Figure 39-A). Micronecta was more abundant of the two species. The maximum catch of this species was 97 individuals in August. A second pulse in November was noted with 62 individuals. Lowest catch was 19 individuals recorded in March. A. hyalinipennis revealed maximum values of 33 individuals in August and 23 individuals in November. It recorded lowest catch of 5 individuals in December.

Like Notonectidae, Gerridae catch was represented by low numbers (Figure 38-B). The maximum catch was seen in August (7 individuals) and the minimum in December (1 individual). The family had only one representative: Limnogonus nitidus (Figure 39-A)

Coleoptera :

Coleoptera indicated almost the same trend of fluctuations as Hemiptera. The catch registered an increase from March onwards, and except for a slight fall in May, the upward trend continued till August, when the peak was attained with 99 individuals. This was followed by a sharp fall in September, but remained almost

Figure 39 : A - Showing the seasonal fluctuations of various species of Hemiptera caught in light-trap.

o——o *Anisops* sp.

o——o *Limnogonus nitidus*

□——□ *Agraptocorixa hyalinipennis*

△——△ *Micronecta* sp.

B - Showing the seasonal fluctuations of various species of Coleoptera caught in light-trap.

o- - -o *Laccophilus* sp.

△——△ *Helochares* sp.

□- - -□ *Guignotus* sp.

o——o *Enochrus* sp.

o——o *Hydraticus vittatus*

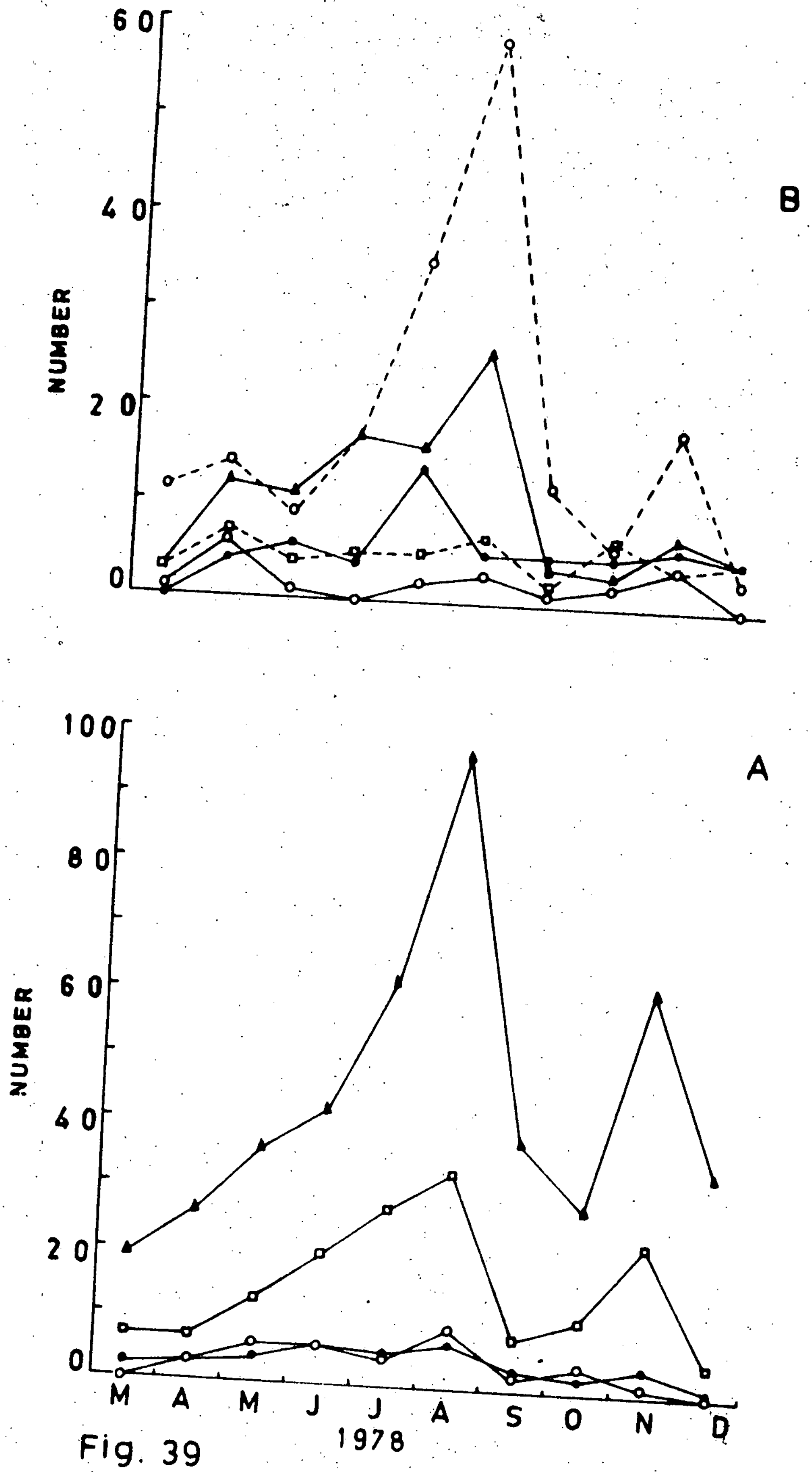


Fig. 39

unchanged during October. The value increased thereafter with a small peak in November (39 individuals), followed again by a decrease (Figure 38-A).

Coleoptera showed maximum catch at 2200-2400 Hrs during the entire period of study, except for March, September and December, when it was recorded at 2000-2200 Hrs. The highest two hourly catch was observed in August with 35 individuals, which accounted for 14.3% of the total for the month. March and December recorded minimum two hourly catch at 0200-0400 Hrs, while April and July recorded the same both at 0200-0400 Hrs and 0400-0600 Hrs. During the other months of the study period, the minimum catch was observed only at 0400-0600 Hrs. Coleoptera recorded nil values at 0200-0400 Hrs in December and at 0400-0600 Hrs in September and October (Table-12).

Coleoptera catch comprised of two families: Dytiscidae and Hydrophilidae.

The Dytiscidae catch was more numerous than Hydrophilidae. The family revealed the same pattern of fluctuations as the order Coleoptera (Figure 38-B). The maximum catch was recorded in August with 68 individuals. Two small peaks were also indicated - one in April (27 individuals) and the other in November (26 individuals). The minimum catch was observed in December with 8 individuals. The family was represented by the following species : *Laccophilus* sp., *Guignotus* sp. and *Hydraticus vittatus* (Figure 39-B). *Laccophilus* was the most abundant of the three species. Like Dytiscidae, the maximum catch was recorded in August having 58 individuals. A small peak was indicated in November with 18 individuals. The lowest catch was in December with a record of 3 individuals. Unlike *Laccophilus*, *Guignotus* sp. was represented by low catch. It failed to show any pronounced peak and the maximum catch of 7 individuals was recorded in April, August and November. Lowest catch of 2 individuals was observed in September. *H. vittatus* represented the lowest catch among the three species. A maximum of 6 individuals was recorded in April. It showed nil values in June and December.

Family Hydrophilidae indicated the same pattern of fluctuations as Dytiscidae except that the peak of maximum catch was observed in July-August (30 and 31 individuals) (Figure 38-B). Moreover, no clear ésecond pulse was indicated in November. The family recorded the lowest catch of 3 individuals in March. Hydrophilidae was represented by two species: *Enochrus* sp. and *Helochares* sp. (Figure 39-B). Fluctuations of *Enochrus* did not differ from the family Hydrophilidae and the maximum catch of 14 individuals was in the month of July. No specimens of the species was caught in March. *Helochares* catch was more abundant than *Enochrus*. Its fluctuations showed the same trend as that for Hydrophilidae. A maximum of 26 individuals were caught in August. The minimum catch of 3 individuals was observed both in March and October.

D I S C U S S I O N

Captures of aquatic insects at light have been recorded from many parts of the world. These records are from Europe, North and South America, Africa, South East Asia and the Far East. Although the phenomenon of flight of aquatic species at night and their attraction to light is a widespread phenomenon, yet records are relatively few especially for Asia, where aquatic insects have not been intensively studied. In India such studies are so few that one can count them by name. Fernando (1958a, 1959a) suggested several causes for the flight of aquatic insects at night. In hot whether the likelihood of dessication is very great for small insects flying in sunshine, and hence flight at night enables insects to travel much farther. There are fewer predators in the air at night as compared to day time. This is largely true because many birds feed on aquatic insects in flight.

The present light-trap studies were carried out for a period of 10 months at Fish Dale, Shillong using a Petromax light. In a region where power failure is a day to day occurrence, the light source for the trap used was found to be quite satisfactory. Jeyasingam et al (1974) used a similar trap in Madurai area, South India. In a recent study, Reddy (1980) used the same trap for terrestrial insects and obtained satisfactory results.

Altogether 1077 individuals of aquatic insects belonging to both Hemiptera and Coleoptera were collected during the study. These insects comprised of 4 genera under Hemiptera and 5 Coleopteran genera. This is comparable to the studies by Sen (1979) who recorded 6 genera of the former and 7 of the latter. On the other hand, Jeyasingam *et al* (1974) recorded only 1 genera of Hemiptera and 5 genera of Coleoptera. However, in a later study, Jeyasingam (1977) obtained the same number of genera recorded by Sen (1979).

In the present investigations it was revealed that the Hemiptera was more attracted towards light than the Coleoptera. The former contributed 62.2% of the total insects while the latter only 37.8%. Monthly catches also showed that Hemiptera was always higher than Coleoptera, except on one occasion. Fernando (1961a, 1961b) based on an extensive work in Malaysian and Ceylonese waters at different seasons of the year, noted that Hemiptera are more attracted to light than Coleoptera. A similar result was also obtained by Jeyasingam *et al* (1974) who found that Hemiptera though represented by a single genus, was more abundant than Coleoptera. The great abundance of Hemiptera may be attributed to the better flying ability of Corixidae which dominated among the families of Hemiptera. It is known that most corixid species are strong fliers and take off easily from the water (Hungerford, 1919). Fernando (1961b) also stated that while the larger species of Corixidae are capable of flying considerable distances, the smaller *Micronecta* are probably carried long distances in aerial plankton. Pajunen and Jansson (1969) found that the corixid populations inhabiting small rock pools were highly dispersive and dispersal was intense enought to enable the corixids to exploit the ephemerality and discontinuity of the habitat.

A two hourly analysis of the total insects and insect orders revealed that maximum catch was recorded during 2000 Hrs to 2400 Hrs, while the minimum catch was obtained during 0400 Hrs to 0600 Hrs. The same pattern was true for both the orders. Yamamoto (1951) noted that the flight of water beetles to a light-trap was greatest within one hour after darkness. Fernando (1963b) concluded that mass migration of aquatic insects takes place during the pre-midnight period. A peak in early half of the night was also observed by Sen (1979). Jeyasingam et al (1974) however, recorded both pre-midnight and post-midnight peaks in their studies. The present study is more in conformity with the findings of Fernando (1963b) and Sen (1979).

The monthly catch of total insects revealed a marked seasonality in the flight of aquatic insects at night. The highest number of insects were recorded in August '78. A second smaller peak was indicated in November. The fall in population was noted in March. The same trend was recorded in both Hemiptera and Coleoptera. Lundblad (1933) suggested passive or active flight helped by winds as the chief means of dispersal of some aquatic insects. Gressit (1954) felt that insects may take advantage of seasonal variation in wind currents. Zimmerman (1948) considered storms an important agency in insect dispersal. In tropical monsoonal countries like Northern Malaya, SriLanka and parts of India, flight of aquatic species is often associated with monsoonal rains (Fernando, 1960). Generally, the monsoonal rains are accompanied by winds of considerable speed or even storms. This is an ideal situation for the dispersal of aquatic forms in the air. Thus, the climatic conditions during the monsoons undoubtedly act as a proximate factor in causing these insects to take to the air. They are then dispersed by the wind currents over considerable distances and the monsoon rains provide suitable habitats which they can colonize (Fernando, 1961b). In the present study, the record of highest number of insects in the traps during the monsoon period during August, therefore, suggests that rainfall and associated climatic conditions might have influenced these insects to take to flight. It has also been shown that flight at night is an important factor in the colonization cycle of some species (Fernando, 1960). That such flight is associated with monsoon season with marked wind currents indicate that rigid restriction of flight period has evolved as an adaptation to colonize habitats and also to disperse the species over a wide area. Besides rainfall and wind current, temperature is another factor which seems to influence the flight of insects considerably. Minimum and mean temperatures are considered the most important factor regulating the nightly activity and light orientation of insects (Hosney, 1959; Pullianen, 1964a, b; Persson, 1971) and have been observed to affect catches (Southwood, 1960; Pullianen, 1965; Iso-Iivari & Koponen, 1976). Landin (1968) also showed that the diel periodicity of flight by some aquatic insects is dependent upon temperature. Similar studies on some Dytiscidae revealed that most flight occurred at temperatures of 23°-24°C when there was no wind. Flights appeared to be limited by temperatures as low as 16°C and as high as 32°C (Zalom et al, 1980b). Light trapping of adult Trichocorixa verticalis showed that there was a negative correlation between abundance and nocturnal ambient air temperature. This correlation indicated that T. verticalis dispersed on cooler nights to minimize water loss that would have been high had they emerged from warm pothole water temperatures into warm ambient air temperature (Campbell, 1979). In the present study, however, no attempt was made to ascertain the role of temperature in the flight of aquatic insects.

The Hemiptera catch of the present investigation included the families Notonectidae, Corixidae and Gerridae. The trend of fluctuations in the three families was almost similar to Hemiptera. Corixidae are the commonest Hemiptera attracted to artificial lights (Fernando, 1961b) and the same was true for the present study. This family comprised of Micronecta sp. and Agraptocorixa hyalinipennis. Micronecta represented the highest abundance among all the species. Notonectidae and Gerridae catches were very low. The former was represented by Anisops sp., while the latter was by Limnogonus nitidus. Both species were recorded at light from SriLanka (Fernando, 1961b).

The Coleoptera catch was represented by the families - Dytiscidae and Hydrophilidae. Both families exhibited more or less the same trend as Coleoptera. Dytiscidae included Laccophilus sp., Guignotus sp. and Hydraticus vittatus. Hydrophilidae was represented by Helochares sp. and Enochrus sp. Laccophilus formed the most abundant among all species of Coleoptera as was also reported by earlier workers (Fernando, 1961a,b; Jeyasingam, 1977).

A few salient facts do emerge from the present light-trap study. A simple light-trap such as the one used during the study can give satisfactory results. Generally, Hemiptera are more attracted towards light than Coleoptera. This may be due to the greater flying abilities of the Corixidae, the ubiquitous family under Hemiptera. The maximum dispersal of the insects takes place during the pre-midnight period, while less activity was recorded during the rest of the period. The insect catch was maximum during the monsoon season, and therefore, rainfall probably influenced the dispersal of these insects. This migrational peak during monsoon could be attributed to the search for food and suitable habitats. The small peak seen in November may be in quest of conducive habitats to overcome the winter months. It was also revealed that independent of the species diversity within the two orders, both the orders showed more or less the same trend of seasonality in dispersal. The present study once again confirms that flight at night is a widespread phenomenon, and involves several species in the case of Hemiptera and Coleoptera.

CHAPTER - III

C O L O N I Z A T I O N O F A R T I F I C I A L S U B S T R A T E S B Y A Q U A T I C I N S E C T

RESULTS

Experiments on the colonization of artificial vegetation by aquatic insects were carried out for a period of one annual cycle in two of the sampling stations mentioned earlier (Chapter 1) i.e. Kyrdemkulai Fish Pond (Station 3) and Ulubari Fish Pond (Station 4). The artificial vegetation used was that of Littorella sp. and Rotala rotundifolia (Pl.8-a,b). Results are dealt separately for each station and substrate.

Station 3 - Kyrdemkulai Fish Pond :

(i) Littorella :

A total of 471 aquatic insects were found to colonize in artificial Littorella during the entire period of investigation with five insect orders represented. The Ephemeroptera showed the maximum number of 150 individuals followed by Odonata (143), Hemiptera (72), Diptera (58) and Coleoptera (48) in that order (Table-13).

Order Hemiptera was largely represented by Micronecta sp. and Diplonychus rusticus. Of the two, the latter was predominant with a total number of 65 individuals. It revealed maximum colonization in December '79 (14 individuals) and minimum in July '7 and May '80 (2 individuals). Micronecta was found only on three occasions and accounted for a total of 7 individuals. A maximum of 4 individuals were recorded in October '79 (Table-14).

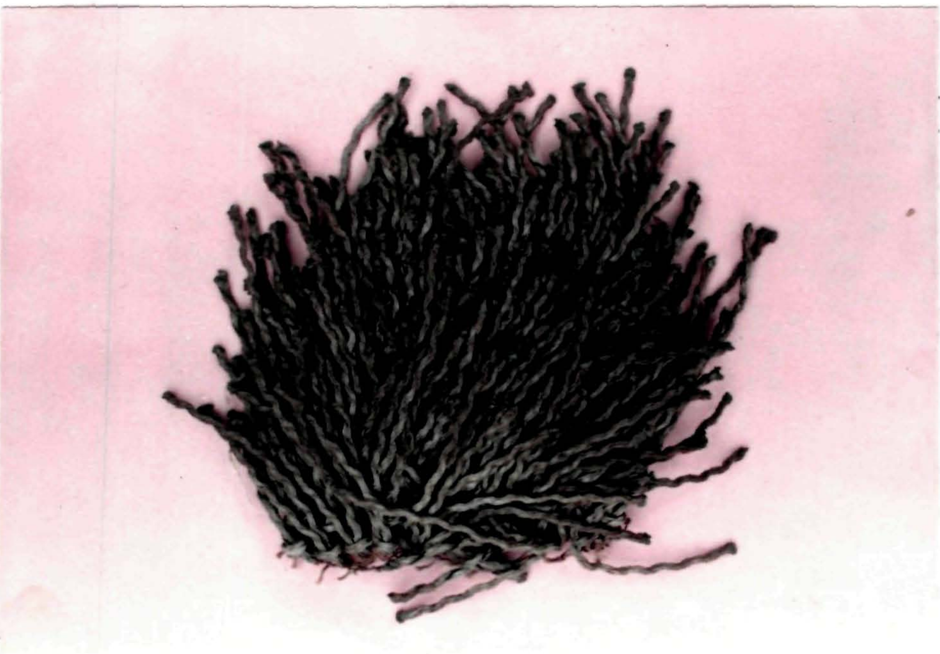
Of the Ephemeroptera, the highest number was represented by Cloeon sp. It recorded a maximum number of 34 individuals in October '79. A second peak though of a relatively less magnit

Plate 3 : Showing the artificial vegetations
made of polypropylene rope.

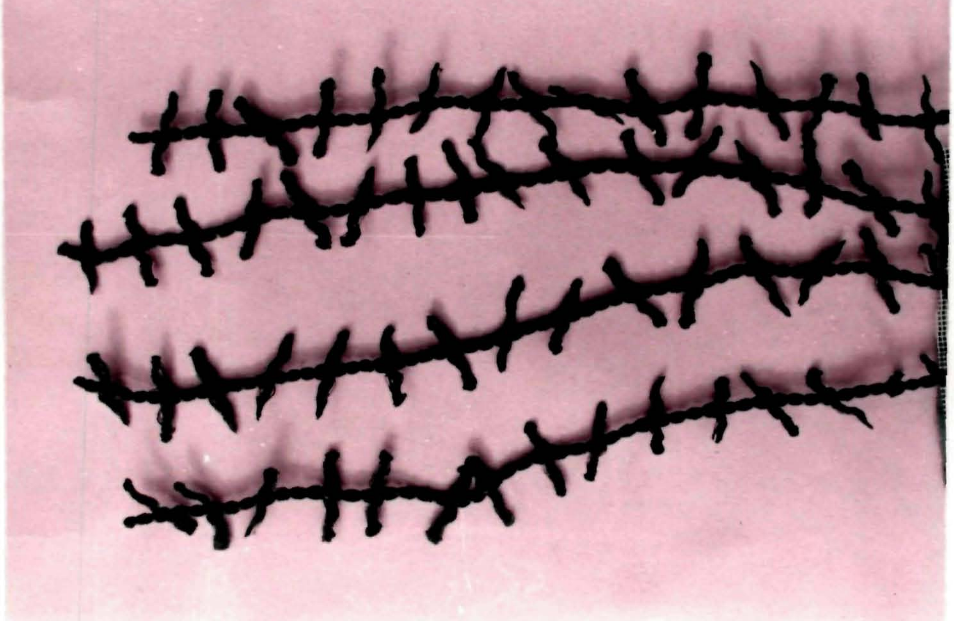
(a) - *Littorella*

(b) - *Rotala rotundifolia*

PLATE-3



a



b

The Odonata was represented by Tramea similata, Lestes sp. and an unidentified Coenagrionidae. The latter was more numerous of the three with a total number of 103 individuals. It revealed a maximum colonization of 21 individuals in November '79. The minimum was seen in May '80. T. similata accounted for a total of 34 individuals with its maximum of 10 individuals in November '79. This species was not found to colonize in August '79, April and May '80. Lestes recorded the lowest density with a total of 6 individuals. It was seen only on three occasions - August, September and November '79, with the maximum of 3 individuals in September (Table-14).

Coleoptera had one representative - Laccophilus sp. with maximum colonization in April '80 with 12 individuals (Table-14).

Anatopynia sp. was the only representative of order Diptera. It revealed maximum number in February '80 (19 individuals). It was found to be absent during July to September '79 and May to June '80 (Table-14).

(ii) Rotala rotundifolia :

The total number of insects which colonized artificial R. rotundifolia was 326 individuals. All the five orders mentioned earlier were recorded in this substrate. Unlike Littorella, R. rotundifolia had the order Odonata representing the highest number of 144 individuals, followed by Ephemeroptera (69), Hemiptera (47), Diptera (35) and Coleoptera (31) (Table-13).

As in Littorella, Hemiptera was represented by Micronecta sp. and Diplonychus rusticus. However, the total numbers that colonized was in the reverse order to that found in Littorella, with Micronecta (30 individuals) recording more than D.rusticus (17 individuals). Micronecta showed maximum colonization in October '79 with 9 individuals. It was totally absent during July '79 and February to April '80. D. rusticus revealed maximum number of 5 individuals in December '79. It failed to occur during July '79, September '79 and April to May '80 (Table-15).

Order Ephemeroptera had only one representative, Cloeon sp.1. It colonized with the maximum in October with 19 individuals. A second maxima was seen in May '80 with 12 individuals. The minimum was observed in July '79 with only 1 individual (Table-15).

Odonata was represented by three species: Tramea similata, Lestes sp. and an unidentified Coenagrionidae. T. similata was the predominant of the three, recording a total of 68 individuals, followed by the unidentified Coenagrionidae with 47 individuals and Lestes with 29 individuals. T. similata was at its maximum in November '79 with 18 individuals. It failed to colonize during April '80. The unidentified Coenagrionidae, like T. similata, also recorded maximum colonization in November '79 with 11 individuals. It recorded nil value in May '80. Unlike the other two species, Lestes colonized maximum in September '79 with 8 individuals. It was completely absent during December '79 and March to April '80 (Table-15).

Order Coleoptera had two representatives: Laccophilus sp. and Gyrinus smaragdinus. The former recorded a total number of 20 individuals, while the latter recorded 11 individuals. Laccophilus was maximum during April '80 with 6 individuals. It was totally absent during September to October '79 and January '80. G. smaragdinus colonized only during November '79 to March '80.

The maximum number was seen in December '79 with 4 individuals (Table-15).

As in the case of Littorella, order Diptera was represented by Anatopynia sp. It showed maximum colonization during February '80 with 10 individuals. However, it failed to colonize during July to August '79, October '79 and June '80 (Table-15).

Station 4 - Ulubari Fish Pond :

(i) Littorella :

The artificial Littorella vegetation in this station was colonized by a total of 747 individuals, which was the highest value for both stations. The insect orders represented were same as in Station 3. Order Ephemeroptera recorded the maximum number as was also seen in Station 3 with a total of 316 individuals. It was followed by Odonata (137), Coleoptera (107), Diptera (96) and Hemiptera (91) (Table-13).

Hemiptera was represented by two species, Micronecta sp. and Plea areolata. The former was more numerous with a total of 62 individuals, while the latter accounted for a total of 29 individuals. Micronecta colonized maximum during July '79 with 17 individuals. It recorded nil value during March '80. Plea areolata colonized only during December '79 to April '80. It revealed maximum numbers during March '80 (Table-16).

Unlike in Station 3, order Ephemeroptera was represented by two species: Cloeon sp.2 and Caenis sp. However, here too Cloeon was predominant with a total of 191 individuals and colonizing during the entire period of study. It recorded maximum numbers during August '79 with 57 individuals. A second maxima was also seen in April '80 with 23 individuals. The minimum number was observed in December '79. *Caenis* revealed a total of 125 individuals during the entire period of study. It showed maximum colonization during December '79 with 41 individuals. It recorded complete absence during July to August '79 and June '80 (Table-16).

Order Odonata had two representatives: *Orthetrum* sp. and an unidentified Coenagrionidae with the latter being more numerous. *Orthetrum* recorded a total of 39 individuals, while the unidentified Coenagrionidae revealed a total of 98 individuals. *Orthetrum* colonized maximum during December '79 with 10 individuals. It showed complete absence during April to May '80. The unidentified Coenagrionidae recorded the maximum during August '79 with 27 individuals. Minimum was during December '79 and March '80 with 3 individuals (Table-16).

Order Coleoptera was represented by four species : *Laccophilus flexuosus*, *Canthydrus laetabilis*, *Berosus fairmairei* and *Berosus pulchellus*. Of these, *L. flexuosus* was found to be the most predominant. It recorded a total of 65 individuals during the entire cycle. The maximum colonization of this species was seen during February '80 (17 individuals), while the minimum was observed to be in May '80. *C. laetabilis*, which recorded a total of 13 individuals, was seen only during July to September '79 and December '79 to February '80. It showed a maximum colonization of 5 individuals in August '79. *B. fairmairei* accounted for a total of 22 individuals. It colonized during December '79 to April '80, with maximum in January '80. *B. pulchellus* revealed the lowest total of 7 individuals. It was seen to colonize only during January to April '80 with maximum in January with 3 individuals (Table-16).

Order Diptera had only a single representative : *Chironomus* sp. It revealed maximum colonization during December '79 with 21 individuals. The minimum value was recorded in August '79 with 2 individuals (Table-16).

(ii) *Rotala rotundifolia* :

The artificial *R. rotundifolia* was colonized by a total of 333 individuals with all the insect orders represented as in *Littorella* beds. Ephemeroptera recorded the highest total of 161 individuals during the entire period of study. It was followed by Odonata (60), Diptera (45), Coleoptera (36) and Hemiptera (31) (Table-13).

As in *Littorella*, order Hemiptera had two representatives : *Micronecta* sp. and *Plea areolata*. The former recorded a total of 21 individuals while the latter 10 individuals. Both the species revealed irregular occurrence. *Micronecta* was seen to colonize during July to October '79 and April to June '80. It recorded maximum during July '79 with 7 individuals. *P. areolata* was observed during January to April '80. It was found to show the maximum during March '80 with 5 individuals (Table-17).

Order Ephemeroptera was represented by *Cloeon* sp.2 and *Caenis* sp. The former with a total of 90 individuals, was more numerous while the latter had 71 individuals. *Cloeon* recorded maximum colonization during August '79 with 26 individuals. It was seen to have a minimum value during January '80. *Caenis* colonized maximum in December '79 with 21 individuals. There was complete absence of the species during July to September '79 and May to June '80 (Table-17).

Order Odonata had two representatives: Orthetrum sp. and an unidentified Coenagrionidae. The latter was predominant throughout the year and accounted for a total of 51 individuals, while the former recorded a total of only 9 individuals. The unidentified Coenagrionidae recorded maximum during August '79 with 10 individuals and minimum during March and May '80. Orthetrum colonized only during November '79 to February '80. The maximum value was seen in January '80 with 4 individuals (Table-17).

Unlike in Littorella, R. rotundifolia had only two representatives of the order Coleoptera: Laccophilus flexuosus and Canthydrus laetabilis. The former was more numerous with a total of 28 individuals, whereas the latter totalled to only 8 individuals. L. flexuosus colonized maximum numbers during February '80 with 8 individuals. It was completely absent during November to December '79 and May '80. C. laetabilis colonized during August to September '79 and December '79 to February '80. It revealed maximum number during January '80 with only 3 individuals (Table-17).

Chironomus was the only representative of the order Diptera. It was found to colonize during the entire period of investigation, except in June '80 with the maximum of 10 individuals in January '80 (Table-17).

TABLE-13 : Showing the density of different insect orders colonized in the two varieties of artificial vegetations (*Littorella* sp. and *Rotala rotundifolia*) at Stations 3 and 4.

TABLE-13

Insect Orders	Kyrdemkulai Fish Pond (Station 3)		Ulubari Fish Pond (Station 4)	
	Litorella sp.	*Rotala rotundifolia*	*Litorella* sp.	*Rotala rotundifolia*
Hemiptera	72	47	91	31
Ephemeroptera	150	69	316	161
Odonata	143	144	137	60
Coleoptera	48	31	107	36
Diptera	58	35	96	45
Total insects	471	326	747	333

TABLE-14 : Showing the density of different species of insects colonized in *Littorella* at Station 3 over the study period.

<u>TABLE-14</u>

Name of the Species	1979						1980						TOTAL
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
1. <u>Micronecta</u> sp.	0	0	1	4	2	0	0	0	0	0	0	0	7
2. <u>Diplonychus</u> <u>rusticus</u>	2	6	4	9	7	14	6	3	3	5	2	4	65
3. <u>Cloeon</u> sp.1	5	9	14	34	18	8	6	5	4	11	27	9	150
4. <u>Tramea</u> <u>similata</u>	2	0	2	4	10	5	2	4	3	0	0	2	34
5. <u>Lestes</u> sp.	0	1	3	0	2	0	0	0	0	0	0	0	6
6. Unidentified Coenagrionidae	4	7	9	7	21	15	10	14	6	4	1	5	103
7. <u>Laccophilus</u> sp.	4	4	2	0	[illegible]	5	3	5	6	12	4	1	48
8. <u>Anatopynia</u> sp.	0	0	0	3	10	7	8	19	7	4	0	0	58

TABLE-15 : Showing the density of different species of insects colonized in *Rotala rotundifolia* at Station 3 over the study period.

TABLE-15

Name of the Species	1979						1980						TOTAL
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
1. *Micronecta* sp.	0	2	5	9	3	2	2	0	0	0	2	5	30
2. *Diplonychus rusticus*	0	1	0	1	3	5	2	2	1	0	0	2	17
3. *Cloeon* sp.1	1	3	4	19	7	2	5	3	4	6	12	3	69
4. *Tramea similata*	6	2	5	9	18	11	5	3	2	0	2	5	68
5. *Lestes* sp.	3	5	8	3	3	0	1	2	0	0	1	3	29
6. Unidentified Coenagrionidae	1	4	4	2	11	9	2	8	3	1	0	2	47
7. *Laccophilus* sp.	2	1	0	0	1	2	0	1	3	6	1	3	20
8. *Gyrinus smaragdinus*	0	0	0	0	2	4	1	3	1	0	0	0	11
9. *Anatopynia* sp.	0	0	2	0	5	4	3	10	6	4	1	0	35

TABLE-16 : Showing the density of different species of insects colonized in Littorella at Station 4 over the study period.

TABLE-16

Name of the Species	1979						1980						TOTAL
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	
1. *Micronecta* sp.	17	10	3	9	4	1	3	2	0	3	4	6	62
2. *Plea areolata*	0	0	0	0	0	2	5	6	12	4	0	0	29
3. *Cloeon* sp.2	25	57	18	10	5	2	8	7	15	23	12	9	191
4. *Caenis* sp.	0	0	3	8	14	41	20	12	16	9	2	0	125
5. *Orthetrum* sp.	4	1	2	6	5	10	2	4	2	0	0	3	39
6. Unidentified Coenagrionidae	12	27	10	7	4	3	9	6	3	5	4	8	98
7. *Laccophilus flexuosus*	3	5	9	6	3	2	8	17	5	3	1	3	65
8. *Canthydrus laetabilis*	2	5	1	0	0	3	1	1	0	0	0	0	13
9. *Berosus fairmairei*	0	0	0	0	0	2	9	3	5	3	0	0	22
10. *Berosus pulchellus*	0	0	0	0	0	0	3	1	2	1	0	0	7
11. *Chironomus* sp.	4	2	3	7	10	21	12	9	6	3	5	14	96

TABLE-17 : Showing the density of different species of insects colonized in *Rotala rotundifolia* at Station 4 over the study period.

TABLE-17

Name of the Species	1979						1980						TOTAL
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
1. *Micronecta* sp.	7	4	1	2	0	0	0	0	0	2	2	3	21
2. *Plea areolata*	0	0	0	0	0	0	2	2	5	1	0	0	10
3. *Cleeon* sp.2	9	26	11	3	5	2	1	6	10	8	5	4	90
4. *Caenis* sp.	0	0	0	4	9	21	11	10	12	4	0	0	71
5. *Orthetrum* sp.	0	0	0	0	2	2	4	1	0	0	0	0	9
6. Unidentified Coenagrionidae	5	10	6	5	2	3	8	5	1	2	1	3	51
7. *Laccophilus flexuosus*	1	5	4	2	0	0	3	8	2	1	0	2	28
8. *Canthydrus laetabilis*	0	1	1	0	0	2	3	1	0	0	0	0	8
9. *Chironomus* sp.	2	4	3	1	7	5	10	7	3	1	2	0	45

D I S C U S S I O N

The present studies on the colonization of artificial *Littorella* sp. and *Rotala rotundifolia* by aquatic insects in Station 3 and 4 revealed that the total number of insects were more in *Littorella* than *R. rotundifolia*, in both the stations. In fact, the total number of insects in Station 4 was more than double in *Littorella* as compared to *R. rotundifolia*. The difference in density was however less pronounced in Station 3. It is interesting to note that even at the level of orders of insects except for the order Odonata in Station 3, *Littorella* always showed greater abundance. The preponderance of insects in *Littorella* may be due to its greater surface area as compared to *R.rotundifolia*. Rosine (1955) suggested that plant surface area is important in determining the number of organisms. It may be also due to the dense cover it provides to insects for protection from predators. This finds support in the works of Macan and Kitching (1972) who observed that artificial *Littorella* provides thicker cover and in turn the animals were more numerous.

It was observed that in Station 3, order Ephemeroptera colonized the highest number in both types of vegetation, followed by Odonata while Hemiptera colonized the lowest number. A similar trend, with Ephemeroptera colonizing the highest number, followed by Odonata was also seen in Station 4, in case of *Littorella*. However, the trend was reversed in *R. rotundifolia*, with Odonata recording the highest number and followed by Ephemeroptera. Coleoptera colonized the lowest in both types of vegetation in Station 4. The factors which determine these preferences are poorly understood and probably vary from species to species (Petr, 1968). One is therefore, tempted to analyse the species composition of insects in these two types of substrata.

Although all the five major orders recorded in population study (Chapter 1) were represented in both types of vegetation, however, only a few species were observed to colonize in both Stations 3 and 4. Out of the 24 species recorded in population study, only 8 species colonized in Littorella at Station 3, while only 9 species colonized in R. rotundifolia. In Station 4, out of the 26 species recorded in population study, only 11 species colonized Littorella, while only 9 species in R. rotundifolia.

Two species of Hemiptera namely Micronecta sp. and D. rusticus colonized both Littorella and R. rotundifolia in Station 3. However, in Station 4, D. rusticus was replaced by Plea areolata in both types of vegetation. Micronecta belongs to the non-predatory family Corixidae, the members of which obtain their food from organic cover of the bottom, from periphyton rich microscopical organisms and from plant detritus. Thus, the preference of Micronecta for artificial vegetation may be due to the fact that both vegetations were covered by masses of inorganic and organic detritus and periphyton. D. rusticus as a predatory Hemiptera feeds on all kinds of aquatic organisms. P. areolata are small Hemiptera which are known to feed mostly on small entomostracans. Their occurrence on artificial substratum may be due to the availability of this type of food therein.

Order Ephemeroptera was represented by a single species - Cloeon in Station 3, true for both types of vegetation. In Station 4, in addition to Cloeon, Caenis sp. also colonized both types of substrata. The greater abundance of Cloeon in artificial vegetation may be correlated with the greater abundance of periphytic diatoms and plant detritus there, which forms the main food source of these insects.

Three species of Odonata colonized both the artificial vegetation in Station 3. They were: Tramea similata, Lestes sp. and an unidentified Coenagrionidae. In Station 4, Odonata had two representatives, Orthetrum sp. in both types of vegetation and unidentified Coenagrionidae. It was revealed that in Station 3, among the species of Odonata, T. similata and Lestes preferred R. rotundifolia more than Littorella, while the reverse was true in the case of unidentified Coenagrionidae. In Station 4, however, both the species preferred Littorella to R. rotundifolia. The preference of Zygopteran nymphs for some species of water plants was observed by Rosine (1955) who found that Lestes nymphs seem to avoid Chara and Polygonum, but commonly occurring in Potamogeton and Utricularia. Further, both the anisopteran nymphs are long-legged sprawlers preying on Oligochaetes, small crustaceans and larvae of aquatic insects.

The species composition of order Coleoptera showed some difference in the two types of vegetation at both the stations. In Station 3, Littorella was colonized by a single species - Laccophilus, while R. rotundifolia was colonized by two species - Laccophilus and Gyrinus smaragdinus. In Station 4, Littorella had 4 species of Coleoptera - Laccophilus flexuosus, Canthydrus laetabilis, Berosus fairmairei and Berosus pulchellus. However, R. rotundifolia was colonized by only two species: L. flexuosus and C. laetabilis. In the present study, among the different species of beetles, Laccophilus was the most predominant

Coleoptera in both stations and in both types of artificial vegetation. Laccophilus, which belong to the family Dytiscidae are predaceous and as such were able to find an abundance of food on both the plants. B. fairmairei and B. pulchellus belong to the family Hydrophilidae, which are known to feed on periphytic algae and decaying vegetation (Pennak, 1953). Their presence only in Littorella may be due to its dense cover.

In case of order Diptera, both types of artificial substrates was colonized by a single species, in both the stations. In Station 3, Diptera was represented by Anatopynia sp., while in Station 4, it was colonized by Chironomus sp. Both the species belong to the family Chironomidae. Most of the Chironomid larvae build tubes of organic detritus and silt. The preference of Chironomid for both the substrate types may be related to their silt load. Petr (1968) also suggested similar preference of Chironomids for Ceratophyllum.

When the seasonality of these insects belonging to five orders were considered, in most cases they revealed similarity with the trends as observed in population study (Chapter I). Among the Hemiptera in Station 3, Micronecta showed autumn maximum, while D. rusticus recorded winter maximum. In Station 4, Micronecta recorded summer maximum and spring minimum, while the reverse was true for P. areolata. In Station 3, Cloeon was seen to have an autumn and summer maxima and a spring minimum, while in Station 4, it showed summer maximum and winter minimum. However, the reverse was true of Caenis. The species of Odonata (T. similata and unidentified Coenagrionidae) in Station 3, recorded early winter maxima and spring minima. A similar trend was also observed in case of Orthetrum in Station 4. The unidentified Coenagrionidae, however, revealed a summer maximum and spring minimum in the same station. Among the species of Coleoptera in Station 3, Laccophilus was seen to have spring maximum and autumn minimum. G. smaragdinus which colonized only in R. rotundifolia recorded winter maximum. In Station 4, out of the four species, Laccophilus revealed maximum during early spring and minimum during early summer months. C. laetabilis mostly showed a winter maximum. B. fairmairei and B. pulchellus which colonized only in Littorella also indicated winter maxima. The order Diptera represented by Anatopynia and Chironomus in Stations 3 and 4 respectively recorded winter maxima and summer minima.

Thus the present study revealed that sampling of aquatic insects employing artificial substrates proved to be an useful tool as a fair measure of the seasonality of these insects. Macan and Kitching (1972) also observed that artificial vegetation provides a useful means of making various comparisons of aquatic insect populations. However, more work is needed in this direction, since the author is fully aware of the limitations of the present study of an exploratory nature.

CHAPTER - IV

PREDATORY PROPENSITIES OF THE DRAGONFLY NYMPH *ORTHETRUM* Sp.

RESULTS

Short term experiments on the predatory propensities of the dragonfly nymph - Orthetrum sp. were carried out during April to July, 1979 under laboratory conditions. The following aspects were studied.

(a) Satiation time :

When an animal no longer accepts offered food after a period of active feeding, it is considered to be fully satiated. The time taken by the animal from the start of feeding to such voluntary cessation is defined as the satiation time (Brett,1971). In the present investigations, to determine for the satiation time, nymphs were starved for a period of 36 to 42 hours before the commencement of feeding experiments. Spawn of the common carp, Cyprinus carpio numbering 10 were introduced into each aquarium containing the nymph. Number of spawn consumed was continuously observed for a total period of 60 minutes at 10 minutes intervals. Care was taken to maintain the density of spawn (D=10 spawn/aquarium) constant by adding spawns.

It was observed that during the initial 10 minutes, the nymph consumed nearly 10 spawn, i.e. 62% of the total consumption during the one hour period. The number of spawn consumed during the subsequent 10 minute intervals decreased to 3, 2, 0.9, 0.0 and 0.0 spawn during the second, third, fourth, fifth and sixth 10-minutes periods respectively (Figure 40-A). Thus within 40 minutes of feeding time the nymph consumed 16 spawns.

It was also revealed that the nymph made 16.8 attacks during the first 10 minutes (Table-18). However, the number of

Figure 40 : A - Showing the number of spawn consumed by the nymph <u>Orthetrum</u> as function of successive 10 minutes interval.

B - Showing the effect of prey density on the number of spawn predated by the nymph - <u>Orthetrum</u> sp.

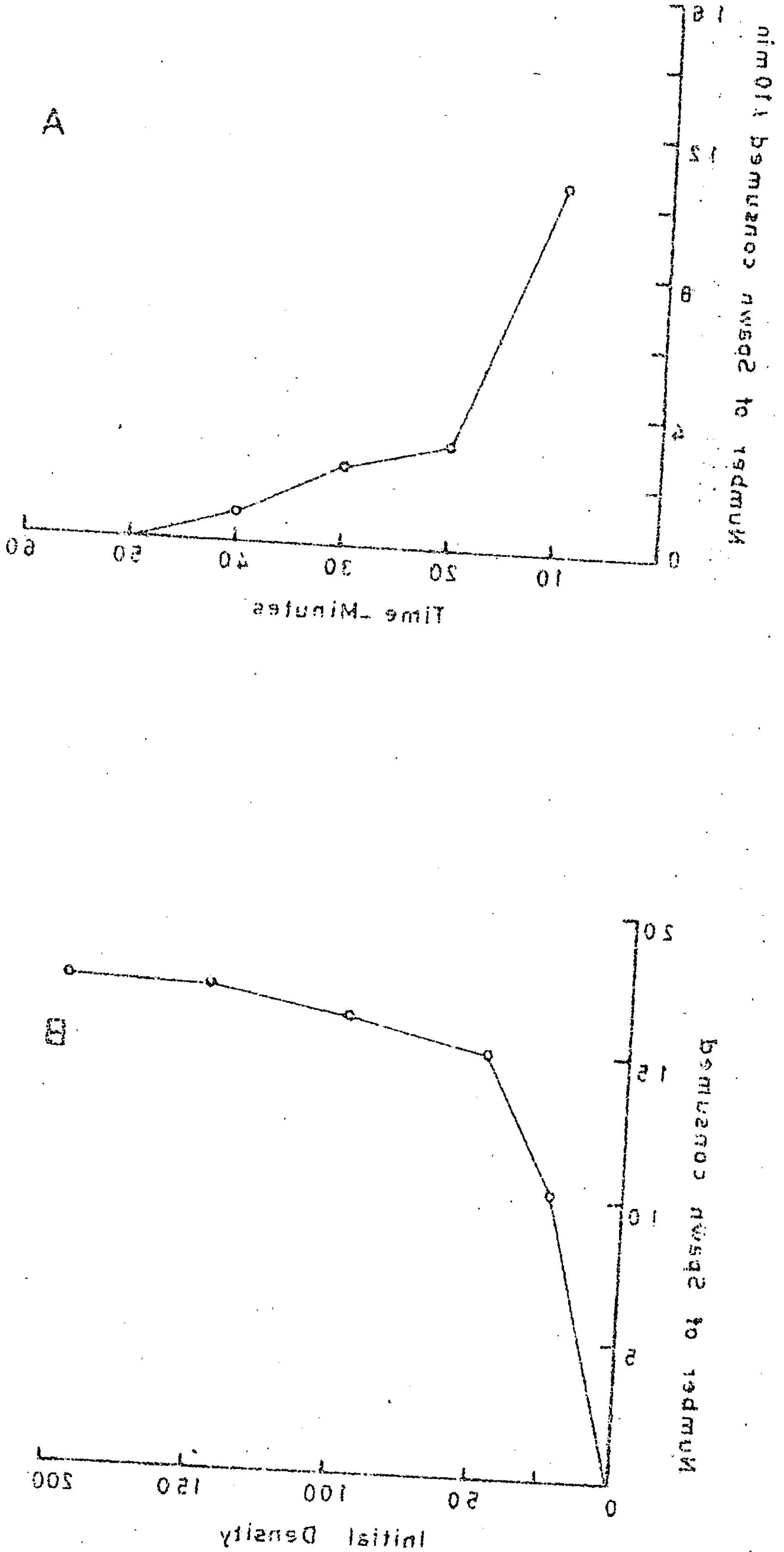

A
Number of Spawn consumed / 10min
Time -Minutes
0
10
20
30
40
50
60
4
8
12
16
B
Number of Spawn consumed
Initial Density
0
50
100
150
200
5
10
15
20

Fig. 40

TABLE-18 : Showing the number and rate of attack of the dragonfly nymph <u>Orthetrum</u> sp. during the successive 10 minutes intervals of feeding. Each value represents the average performance of 10 individuals.

TABLE-18

Duration of intervals	Number of attack	Number of successful attack	Rate of attack (no/min)	Rate of successful attack (no/min)
First 10 min	16.8 ± 1.93	10.5 ± 0.94	1.68 ± 0.19	1.05 ± 0.18
Second 10 min	9.8 ± 1.02	3.0 ± 0.67	0.98 ± 0.10	0.30 ± 0.06
Third 10 min	8.6 ± 1.01	2.3 ± 0.47	0.86 ± 0.10	0.23 ± 0.05
Fourth 10 min	5.0 ± 0.67	0.9 ± 0.32	0.50 ± 0.07	0.09 ± 0.03
Fifth 10 min	0.0	-	-	-
Sixth 10 min	0.0	-	-	-

attacks decreased with advancing time. No attack was made by the nymph during the fifth and sixth 10-minute periods. An attack was considered successful, when the nymph managed to capture and consume the prey. It was seen that not only the total number of attacks decreased with advancing time, but also the number of successful attacks decreased from 10.5 attacks during the initial 10 minutes (Table-18) to 0.0 attacks during the fifth 10 minutes period.

It was noted that the rate of attack (number of attack/minute) was 1.68/min. during the first 10 minutes, of which 1.05 was successful. During the fourth interval, the rate of attack was 0.9/min., of which only 0.09/min. was successful (Table-18). The number of successful attacks expressed as percentage of total number of attacks made by the nymph gives what may be termed as predatory efficiency (Mathavan, 1976). This efficiency decreased in the present experiment from 62% during the first 10 minutes to 30%, 26% and 18% during the successive 10 minute intervals respectively. From the above observations it is clear that within a period of 40 minutes of feeding, the nymph is fully satiated indicative of the satiation time for the species: *Orthetrum*.

(b) Effect of deprivation time :

Holling (1966) used voluntary food intake as a measure of appetite. Mathavan (1976) used the amount of food consumed by dragonfly nymph in relation to deprivation time as an objective assessment of hunger. In order to study the effect of hunger on the dragonfly nymph, test individuals were deprived of food for 6, 12, 18, 24, 36 and 42 hours. They were subsequently exposed to a constant supply of 10 spawn of C. carpio. Observation were made continuously for a period of 1 hour.

It was revealed that the number of prey consumed by a nymph previously starved for 6 hours amounted to 3 spawns (Table-19). The number increased to 7, 10 and 15 in nymphs starved for 12, 18 and 24 hours respectively. However, the number remained constant at 16 spawn, in nymphs starved for 36 to 42 hours. The increased number of prey organisms predated and consumed by the nymph, which was previously starved for different periods increased the satiation time. The nymph deprived for 6 hours satiated after predating 3 larvae in about 18 minutes; the values progressively increased for the nymph deprived for 12, 18 and 24 hours (15 spawn in 36 minutes). In the nymphs deprived for 36 and 42 hours, both the maximum number of spawn predated (16.8) and the satiation time (38 minutes) were more or less similar to the nymph deprived for 24 hours. Thus, it can be inferred that between 24 and 36 hours of starvation, the maximum appetite is resumed.

Considering the initial feeding period of 60 minutes, mean rate of attack of the nymphs exposed to a constant supply of 10 spawn after a period of 6, 12, 18, 24, 36 and 42 hours of starvation was calculated (Table-19). It was seen that the rate of attack was low (0.23/min.) in the nymph fed after 6 hours of deprivation. However, the attack increased to 0.62 attack per minute in nymph fed after deprivation of 24 hours and levelled off at 0.69 attack per minute in nymph fed after 36 hours of deprivation.

(c) Effect of prey density :

For studying the effect of prey density on the predatory

TABLE-19 : Showing the effect of food deprivation duration on the number of spawn predated, satiation time and rate of attack of the nymph - <u>Orthetrum</u> sp. Each value is based on 6 observations.

TABLE-19

Period of deprivation (hr)	Number of spawn consumed	Satiation time (min)	Rate of attack (no/min)
6	3	18	0.23
12	7	24.8	0.37
18	10	28.8	0.40
24	15	36.2	0.62
36	16.8	38.2	0.69
48	16.8	38.3	0.69

behaviour of the nymph Orthetrum sp., test nymphs were starved for a period of 36 hours. They were offered spawn of C. carpio at densities of 25, 50, 100, 150 and 200 spawn/aquarium for a period of 30 minutes.

It was revealed that the mean number of spawn consumed by the nymph increased from 10.2 spawns at the density of 25/aquarium to 15, 16.1, 17 and 17.2 spawn at the density of 50, 100, 150 and 200 per aquarium respectively (Figure 40-B). The satiation time (to predate 16 spawn) for the nymph was about 40 minutes at prey density of 10 spawn/aquarium, whereas it took only 30 minutes for a nymph exposed to a density of 200 spawn/aquarium.

D I S C U S S I O N

Predation of fish by a number of aquatic insects such as Notonecta, Nepa, Dytiscus and Cybister have been studied by several workers (Ganguly and Mitra, 1961; Dahm, 1972; Rise,1975). However, very little experimental work has been done on the predation of fish by Odonate nymphs. Among the Odonata, dragonfly (Sub-order: Anisoptera) nymphs are predatory and are observed to feed on carp spawn (Jhingran, 1978). Hati and Ghosh (1965) observed that the dragonfly nymph, Brachytron pratense attacked and devoured young fishes in the absence of other food. The present studies on the predatory behaviour of Orthetrum sp. had revealed that it deserves consideration as a potential predator of fish spawn in nursery ponds.

Alikunhi et al (1952) reported on his preliminary observations that a specimen of dragonfly nymph (15 mm long) can swallow 7 carp spawn (6-7 mm in length) within 3 hours in the laboratory. The present study however showed that the Orthetrum has greater predatory capacity consuming as many as 16 spawns. Mathavan (1976) reported that Orthetrum sabina consumed about 22 mosquito larvae (Culex fatigans). The present study further revealed that there was considerable decline of predation rate after 10 minutes of feeding of the nymph Orthetrum. Ellis and Borden (1970) and Mathavan (1976) recorded similar precipitous decline of predation rate in Notonecta undulata and Mesogomphus lineatus respectively. It was observed that as flies were killed by the mantis Hiarodula crassa, there was a resulting decrease in the mantis hunger, which in turn caused a precipitive decline in attack rate until hunger was stabilized (Holling, 1966). Mathavan (1976) noted that, when the stomach of the predator is full, they cease feeding and attacking the prey. He pointed out that predators like M. lineatus made random attacks when an undigested bulk of food is present in the stomach, but these are not usually rewarded with success. In the present investigation, it was seen that the 'predatory efficiency' of the nymph decreased gradually from 62% in the first 10 minutes to 18% in the fourth 10 minutes interval. Similar decrease of 'predatory efficiency' was also noted by Mathavan (1976) and Srivastava and Suri Babu (1982) in dragonfly nymphs.

Mathavan (1976) observed that in a prey-predator interaction in which both the predator and the prey are mobile, satiation time involves two important aspects: (i) Predation and (ii) Consumption (= handling time). In the present study the nymphs required 85 seconds to consume a captured spawn. Thus, the handling time for 16 spawn is about 22 minutes. The remaining 18 minutes of the 40 minute satiation period were spent by the nymph on predation.

It was also revealed that increased number of spawn was predated and consumed by the nymph, which was deprived of food for different duration of time periods with a corresponding increase in the satiation time. The predators renewed attack on the prey when appetite was partially or fully resumed. It was shown for this species that between 24 and 36 hours of deprivation, the maximum appetite is returned.

The present investigation indicated that at high densities of prey, the satiation time to predate and consume 16 spawns was only 30 minutes. It was seen frequently that at high prey densities the nymph captured either 2 spawn or captured one; while the previously caught one was being consumed. Thus the time required for predation and consumption could not be very clearly demarcated and recorded. Therefore, duration required for predation of a single spawn as well as consumption of the same were less in the high prey densities than corresponding ones at low densities. Mathavan (1976) also held a similar view.

CHAPTER - V

GENERAL SURVEY OF AQUATIC INSECTS IN 20 LENTIC SYSTEMS

General Survey of Aquatic Insects in 20 Lentic Systems.

A general survey of aquatic insects was carried out during one annual cycle (January to December '79) at twenty lentic systems located at different altitudes starting from Upper Shillong (1790 M above MSL) to the valleys of Gauhati (60 M above MSL). Sampling of insects were made during the summer and winter seasons. The lentic systems covered during the survey included managed fish-ponds, depressions filled with rain water, small water bodies of natural occurrence, man-made ponds and a lake (Table-20). The two largest systems are Ward's Lake at Shillong and Dighali Tank at Gauhati. The former has a total area of 23,800 sq.m with an average depth of 3.4 m, while the latter has an area of 5,000 sq.m with an average depth of 5.5 m. The other systems are much smaller in size ranging from an area of 5 sq.m to about 600 sq.m. Nine of these systems are used for fish culture operations.

Altogether 51 species of aquatic insects were recorded during the survey. These insects belong to the orders: Hemiptera, Ephemeroptera, Odonata, Coleoptera and Diptera. Order Coleoptera was represented by the maximum number with 20 species, followed by Hemiptera (15), Odonata (7), Diptera (6) and Ephemeroptera (3). The relative abundance of different species during the summer and winter seasons are represented in Tables-21 (a,b,c) and 22 (a,b,c) respectively.

It was revealed that among the Hemiptera, *Anisops* sp., *Anisops bouvieri*, *Agraptocorixa hyalinipennis*, *Micronecta* sp., *Limnogonus nitidus* and *Neogerris parvulus* were common species

Table-20 : Showing the lentic systems of the general survey studies, along with the altitudes at which they are situated.

TABLE-20

Sl.No.	Name of the System		Altitude	Type of the System
1.	Upper Shillong pool	-	1780 m	Rain pool
2.	Nongthymmai pond	-	1560 m	Natural pond
3.	Hyderi Park pond	-	1550 m	Man-made pond
4.	Ward's Lake **	-	1545 m	Man-made lake
5.	Ward's Lake pond **	-	1545 m	Man-made pond
6.	Golf-link pond	-	1445 m	Natural pond
7.	Mawlai pond	-	1445 m	Natural pond
8.	Pologround pond	-	1440 m	Natural pond
9.	Pynursla pond	-	1400 m	Man-made pond
10.	Pynursla pool	-	1400 m	Rain pool
11.	Jowai pond **	-	1220 m	Man-made pond
12.	Barapani pond	-	960 m	Natural pond
13.	Nayabunglow pool	-	820 m	Rail pool
14.	Nayabunglow pond **	-	820 m	Man-made pond
15.	Burnihat pond **	-	70 m	Man-made pond
16.	Burnihat Forest Hostel Pond	-	70 m	Man-made pond
17.	Dighali Tank **	-	60 m	Man-made pond
18.	Dighali nursery pond **	-	60 m	Man-made pond
19.	Jhalukbari pond **	-	60 m	Man-made pond
20.	Kahikuchi pond **	-	60 m	Man-made pond

** System used in Fish-culture.

for many stations. While Anisops sp. was predominant in higher altitudes water bodies, A. bouvieri was abundant in systems at lower altitudes. A. hyalinipennis and Micronecta were recorded at both higher and lower altitudes. Surprisingly, it was observed that A. hyalinipennis was more abundant in summer at lower altitude and in winter at higher altitude. The remaining species were present only in some of the stations. While Diplonychus rusticus, Plea areolata and Ranatra elongata were recorded at lower altitude systems, Metrocoris femoratus was observed only at higher altitudes.

Among the three species of Ephemeroptera, Cloeon sp.1 and Cloeon sp.2 were the most abundant groups. It is interesting to note that while Cloeon sp.1 was recorded at higher altitudes, Cloeon sp.2 occurred only at lower altitudes. The third species - Caenis was present only at five stations, irrespective of the altitudes. It was also noted that both the species of Cloeon were more abundant during the summer than in the winter.

Out of the seven species of Odonata, the unidentified Coenagrionidae was the common species in many of the stations surveyed, and it was true for both the seasons. Orthetrum sp. was recorded in nine stations both at high and low altitudes. Two other species- Coenagrion fallax and Lestes sp. occurred only at higher altitudes. The remaining species occurred only in a few stations at both altitudes.

Among the Coleoptera, Gyrinus smaragdinus, Laccophilus sp., Hydaticus vittatus and Cybister sp. were recorded at both higher and lower altitudes systems, irrespective of seasons. It was seen that while Dineutus unidentatus, Laccophilus flexuosus, *Laccophilus sindensis*, *Berosus pulchellus*, *Canthydrus laetabilis*, *Amphiops pedestris*, *Regimbartia attenuata* and *Hyphoporus elevatus* occurred only in lower altitude systems, *Cybister sugillatus*, *Cybister convexsus*, *Rhantus pulverosus*, *Guignotus* sp., *Guignotus flammulatus*, *Enochrus* sp. and *Helochares* sp. are recorded only at higher altitudes. Except for a few, these species did not show much difference during the two seasons.

Out of the six species of Diptera, *Anatopynia* sp., *Brillia* sp. and *Polypedilum* sp. were present at higher altitude systems, while *Chironomus* sp. and *Tanypus* sp. were recorded at lower altitudes. It was noted that while *Brillia* sp. was more abundant during the summer, *Anatopynia* and *Chironomus* were more numerous during the winter seasons. Unidentified culicidae larvae were recorded at both higher and lower altitude systems and were more abundant during the summer seasons.

Thus it is clear that there occur some degree of altitudinal zonation among the aquatic insects of the five orders. While some of the species occurred mostly at higher altitude systems, other species were common at lower altitudes. However, a third group of insects were found at both high and low altitudes water bodies. It may be also stated that while some of the species were more abundant during the summer seasons, a few others were more common during the winter seasons. A third group of insects did not show much change during the two seasons.

A perusal of the Tables-21 and 22 revealed that the total number of species recorded from higher altitude systems were more than that of the systems at lower altitudes. However, it was also indicated that there is an increasing tendency of abundance as one moves from higher altitudes down to the foot hills. A multitude of factors probably govern these altitudinal and seasonal differences. A detailed knowledge of the various physico-chemical factors is necessary to pinpoint the causative factor for these changes. However, it may be pointed out that temperature, which varies with the altitudes, may be one of the major factors responsible for the changes in species composition and abundance of insects in the various systems. Life-cycle periodicity, migration, availability of suitable food and substrates are other probable factors which will also influence such changes.

Again, when the total number of species are taken into account, man-made systems did not reflect much difference from the natural water bodies. Nevertheless, it is of interest to note that the highest number of 22 species were recorded from the Golf-Link pond, a natural system. Except for Pynursla rain pool, the other two rain pools recorded lower number of species. The two largest systems - namely the Ward's Lake and the Dighali Tank, recorded 12 and 15 species respectively. The lowest number of 8 species were recorded from a man-made managed system, the Kahikuchi pond at the foot-hills of Gauhati. Thus, it may be said that natural water bodies with less human interference harbour more species than the managed systems with much human activity as would be expected.

The general outcome of such a survey helped not only to identify the species composition of aquatic insects as in the present study, but also indirectly helped to identify the status of freshwaters in the region under consideration. Thus most man-made systems certainly reflected either the meso-trophic or eutrophic levels and in turn harboured insects which have marked rise and fall in population levels, a small species diversity with higher abundance of each. On the other hand, the high altitude systems akin to sub-temperate situations are of oligotrophic nature, yet offer more ecological niches, and in turn a greater species composition though with low density of each species. The present survey thus helped to obtain an overview of not only the insect populations, but also the nature of the water bodies in this region.

TABLE-21(a) : Showing the insect species of the order Hemiptera and their relative abundance at 20 lentic systems during the summer season.

Hemiptera

1. Anisops sp.
2. Anisops battillifrons Lundblad
3. Anisops bouvieri Kirkaldy
4. Enithares ciliata Fabr.
5. Agraptocorixa hyalinipennis Fabr.
6. Micronecta sp.
7. Diplonychus rusticus Fabr.
8. Plea areolata Paiva
9. Laccotrephes grossus Fabr.
10. Ranatra elongata Fabr.
11. Ranatra filiformis Fabr.
12. Limnogonus nitidus Mayr.
13. Neogerris parvulus Stal
14. Metrocoris femoratus Paiva
15. Gerris adelaidis Dohrn.

TABLE-21 (a)

Name of the system	Hemiptera														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Upp.Shillong pond	+				+				+						
2. Nongthymmai pond	+								+						
3. Hyderi Park pond	+				++	+						+	+		+
4. Ward's Lake	+++				+	++					+	+	+		+
5. Ward's Lake pond	++				+	+									+
6. Golf-link pond	++				++	+			+		+	+			
7. Mawlai pond	+				+				+						
8. Pologround pond	+				++				+			+			
9. Pynursla pond	++				++				+			+		+	
10. Pynursla pool	++				+++						+	+		++	
11. Jowai pond	++			+	++	+					+	+	+		
12. Barapani pond	+	+								+	+	+	+		
13. Nayabunglow pool		+					++								
14. Nayabunglow pond	+	+++		++			+	++		+			+		
15. Burnihat pond			++	+		+	+				+		+		
16. Burnihat Forest Hostel pond			++	+	++	+					+				
17. Dighali Tank			+++		++	++	+			+			+		+
18. Dighali Nursery Pond			+++		++	++		+		+	+		+		
19. Jhalukbari pond			++		+	++							+		
20. Kahikuchi pond			++		++	+									

Key :- +++ = Abundant; ++ = Common; + = Present

TABLE-21 (B) Showing the insect species of the orders Ephemeroptera, Odonata and Diptera with their relative abundance at 20 lentic systems during the summer season.

Ephemeroptera

16. Cloeon sp.1
17. Cloeon sp.2
18. Caenis sp.

Odonata

19. Coenagrion fallax (Ris)
20. Lestes sp.
21. Orthetrum sp.
22. Anax nigrofasciatus nigrolinatus Fraser
23. Unidentified Coenagrionidae
24. Unidentified Libellulidae
25. Tramea similata Rmb.

Diptera

26. Anatopynia sp.
27. MBrillia sp.
28. Chironomus sp.
29. Tanypus sp.
30. Polypedilum sp.
31. Unidentified Culicidae

TABLE-21 (b)

Name of the system	Ephemeroptera			Odonata							Diptera					
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1. Upp.Shillong pool	+				+			+	+							
2. Nongthymmai pond				++		++	+									
3. Hyderi Park pond	++			+		+		+	+		+	++				+
4. Ward's Lake	+++		+					+	+			+				
5. Ward's Lake pond	++		+	+		+	+	++			+	+			+	+
6. Golflink pond	++		+	+		+	+	+				+			+	
7. Mawlai pond					++		+			+	+					
8. Pologround pond	++							+			+	++			+	
9. Pynursla pond	+++			++				++	++							++
10. Pynursla pool	++				+			+	+							+++
11. Jowai pond	+++							++		+++	+					+
12. Barapani pond	+							+		++					++	+
13. Nayabunglow pool	++				+		+	+								+
14. Nayabunglow pond	++							++		+						
15. Burnihat pond		++	++			+			+	+			+++			
16. Burnihat Forest Hostel pond		++	++			++							++	+		++
17. Dighali Tank		+++						++		+						
18. Dighali Nursery Pond		++						+					+	+		
19. Jhalukbari pond		++				+		++					+	+		
20. Kahikuchi pond		+++				+		++								

Key :- +++ = Abundant; ++ = Common; + = Present

TABLE-21(c) : Showing the insect species of order Coleoptera and their relative abundance at 20 lentic systems during the summer season.

Coleoptera

32. *Gyrinus smaragdinus* Regimbart
33. *Dineutus unidentatus* Aube.
34. *Laccophilus flexuosus* Aube.
35. *Laccophilus sindensis* Vazirani
36. *Laccophilus* sp.
37. *Hydraticus vittatus* (Fab.)
38. *Berosus pulchellus* W.M'Leay
39. *Cybister* sp.
40. *Cybister sugillatus* Erichson.
41. *Cybister convexus* Sharp.
42. *Rhantus pulverosus* Stephens.
43. *Canthydrus laetabilis* (Walker)
44. *Amphiops pedestris* Sharp.
45. *Guignotus flammulatus* (Sharp).
46. *Guignotus* sp.
47. *Regimbartia attenuata* (F).
48. *Enochrus* sp.
49. *Helochares* sp.

<u>TABLE-21(c)</u>

Name of the system	Coleoptera																	
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1. Upp.Shillong pool	++										+							
2. Nongthymmai pond					+				+	+	++				+			
3. Hyderi Park pond	+								+		+							
4. Ward's Lake																		
5. Ward's Lake pond					++			+						+	+			
6. Golf-link pond	+				+	+		+	+		++			+			++	
7. Mawlai pond								+										
8. Pologround pond	+				+	+				+	+			+	+		+	+
9. Pynursla pond	+				+			+			+				+			
10. Pynursla pool	+				+	+		++		+	+							
11. Jowai pond						+			+		+							
12. Barapani pond							+											
13. Nayabunglow pool		+			++			+										
14. Nayabunglow pond		++			+		+											
15. Burnihat pond	+	+			+	+			+									
16. Burnihat Forest Hostel pond			++	+														
17. Dighali Tank			++	+			+					++	+					
18. Dighali Nursery pond			+									++				++		
19. Jhalukbari pond			+	+									+			+		
20. Kahikuchi pond			+													++		

Key : +++ = Abundant; ++ = Common; + = Present

TABLE-22(a) : Showing the insect species of the order Hemiptera and their relative abundance at 20 lentic system during the winter season.

Hemiptera

1. Anisops sp.
2. Anisops batillifrons Lundblad
3. Anisops bouvieri Kirkaldy
4. Enithares ciliata Fabr.
5. Agraptocorixa hyalinipennis Fabr.
6. Micronecta sp.
7. Plea areolata Paiva
8. Laccotrephes grossus Fabr.
9. Ranatra filiformis Fabr.
10. Limnogonus nitidus Mayr.
11. Neogerris parvulus Stal
12. Metrocoris femoratus Paiva
13. Gerris adelaidis Dohrn.

TABLE-22 (a)

Name of the System	Hemiptera												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Upp.Shillong pool					Dried	up	in		winter				
2. Nongthymmai pond	+				+			+					
3. Hyderi Park pond					++				+				
4. Ward's Lake	+				+					+			++
5. Ward's Lake pond	++				++	+							+
6. Golf-link pond	+				+++	+		+	+				
7. Mawlai pond	+				+			+					
8. Pologround pond	+				++								
9. Pynursla pond	+				+			+	+			+	
10. Pynursla pool					Dried	up	in		winter				
11. Jowai pond	+				+	+							
12. Barapani pond	+	+							+	+			
13. Nayabunglow pool					Dried	up	in		winter				
14. Nayabunglow pond	+	++		+					+		+		
15. Burnihat pond			++	+					+		+		
16. Burnihat forest Hostel pond			++										
17. Dighali Tank			+		++	+	+				+		
18. Dighali nursery pond			++		+	+	+		+	+	++		
19. Jhalukbari pond			+		+	+			+				
20. Kahikuchi pond			++		++		+		+				

TABLE-22(b) : Showing the insect species of the orders Ephemeroptera, Odonata and Diptera with their relative abundance at 20 lentic system during the winter season.

Ephemeroptera

14. *Cloeon* sp.1
15. *Cloeon* sp.2
16. *Caenis* sp.

Odonata

17. *Coenagrion fallax* (Ris).
18. *Lestes* sp.
19. *Orthetrum* sp.
20. *Anax nigrofasciatus nigrolinatus* Fraser
21. Unidentified Coenagrionidae
22. Unidentified Libellulidae
23. *Tramea similata* Rmb.

Diptera

24. *Anatopynia* sp.
25. *Brillia* sp.
26. *Chironomus* sp.
27. *Tanypus* sp.
28. *Polypedilum* sp.
29. Unidentified Culicidae

TABLE-22(b)

Name of the system	Ephemeroptera			Odonata							Diptera					
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1. Upp. Shillong pool						Dried		up	in	winter						
2. Nongthymmai pond	+			++		+	+	[illegible]			++	+				+
3. Hyderi Park pond	+					+		+								
4. Ward's Lake	++		+			+		+			++	+				++
5. Ward's Lake pond	+					+		+	+		++					+
6. Golf-link pond	+					+		++								
7. Mawlai pond					+				+		+	+				
8. Pologround pond	+							++								
9. Pynursla pond	++				+			+	+							
10. Pynursla pool						Dried		up	in	winter						
11. Jowai pond	++							+		+		+				
12. Barapani pond	+							+		+					+	+
13. Nayabunglow pool						Dried up in winter										
14. Nayabunglow pond	+++							+		+		++				
15. Burnihat pond		++	+			++		++					+++			
16. Burnihat Forest Hostel pond		++	+					++					++	+		+
17. Dighali Tank		++	+					+					++			
18. Dighali Nursery pond		+											++			
19. Jhalukbari pond		++	+			++		+					++	+		+
20. Kahikuchi pond		++	+										+++	++		

Key :- +++ = Abundant; ++ = Common; + = Present

TABLE-22(c) : Showing the insect species of the order Coleoptera and their relative abundance at 20 lentic systems during the winter season.

Coleoptera

30. *Gyrinus smaragdinus* Regimbart
31. *Dineutus unidentatus* Aube.
32. *Laccophilus flexuosus* Aube.
33. *Laccophilus sindensis* Vazirani
34. *Laccophilus* sp.
35. *Hydraticus vittatus* (Fab).
36. *Berosus pulchellus* W.M'Leay
37. *Cybister* sp.
38. *Cybister sugillatus* Erichson
39. *Cybister convexus* Sharp.
40. *Rhantus pulverosus* Stephens
41. *Canthydrus laetabilis* (Walker)
42. *Amphiops pedestris* Sharp.
43. *Guignotus* sp.
44. *Hyphoporus elevatus* Sharp.
45. *Enochrus* sp.

TABLE-22(c)

Name of the system	Coleoptera															
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1. Upp. Shillong pool						Dried		up	in	winter						
2. Nongthymmai pond					+				+	+	++			+		
3. Hyderi Park pond								+								
4. Ward's lake					+									++		+
5. Ward's lake pond					+									++		
6. Golf-link pond	+					++			+	+				+		+
7. Mawlai pond					+											
8. Pologround pond						+								+		
9. Pynursla pond					+						+			+		
10. Pynursla pool						Dried		up	in	winter						
11. Jowai pond						+			+							
12. Barapani pond						+										
13. Nayabunglow pool						Dried		up	in	winter						
14. Nayabunglow pond					+				+					+		
15. Burnihat pond						+			+					[illegible]		
16. Burnihat Forest Hostel pond				+								+				
17. Dighali Tank			++	+												
18. Dighali Nursery pond		++	++				++									
19. Jhalukbari pond		+		+												
20. Kahikuchi pond							++					+	+		++	

Key : +++ = Abundant; ++ = Common; + = Present

GENERAL DISCUSSION

The present investigation was undertaken to obtain base line information on aquatic insects, in certain man-made freshwater ecosystems, to recognise their academic and applied importance. It is known that most of these insects spend their immature life in water with their adult life in the terrestrial environment. Invariably these immature stages are the extended part of their life history. Therefore, in any evaluation of the impact that changes in environment have on aquatic ecosystems, the role of these insects is to be considered, as their immature stages often comprise a high proportion of the biomass in freshwaters. It is well known that any rehabilitative or management strategy characterized by a high probability for success in fish growth, must rely on fundamental knowledge of the intricacies of freshwater ecosystem structure and function. However, the present paucity of information on the general ecology of aquatic insects in the region under consideration was the major imperative for undertaking the present study.

The results of the present study when collated seem to possess some salient features, which in turn are identified for detailed investigations at a future date. One emerging fact was that density in numbers as far as all the insects are concerned was inversely proportional with altitude wherein these systems are located. Generally, the density increased from higher altitude towards the foot of the hills. It was always the reverse order when biomass was considered. This phenomenon was true even when the insects were categorized into major orders like Hemiptera, Coleoptera and Odonata with a few exceptions. Hemiptera was usually seen to be the dominant group, with Ephemeroptera and Odonata following closely behind.

In general, the seasonality of occurrence of these insects had an autumn or early winter peak, though Hemiptera, Ephemeroptera and Odonata possessed summer peaks at the foot hills. The higher altitude Ephemeropteran and Dipteran forms, usually had an early winter or late spring maximum. It was also seen that the magnitude of fluctuations in biomass generally followed the rise and fall of density fluctuations. Rarely the peaks showed a time lag of more than a month. Among the physico-chemical factors recorded, all the factors more or less exhibited a spring or summer maxima and winter minima, with pH dominating on the acidic side at higher altitude, while being alkaline at lower elevations at the foot hills. Even though there existed a constancy of fluctuations in the physico-chemical parameters of the different habitats, yet they did not seem to affect the biotic component in the same way. Thus, order Hemiptera seemed largely to be affected by temperature and rainfall, with rate of colonization enhanced by their migration and ability to fly faster. Order Ephemeroptera though did synchronise with temperature fluctuations in an inverse pattern, yet seemed largely to be controlled by the amount of detritus and life history periodicity. In case of Odonata, Coleoptera and Diptera, the physico-chemical parameters appear to have very little influence on the population dynamics over the seasons. For these last groups of insects the submerged and emergent vegetation, detritus and the suitability of substrate had greater impact than the variation of the abiotic factors.

Despite these general observations, when a linear correlation and multiple correlation analysis were performed for the various orders of insects and the abiotic factors, it was seen that at higher altitudes, Ephemeroptera and Diptera had negative correlation with most of the factors. Nevertheless, Odonata and Coleoptera showed positive significant relationship with temperature, the former at the foot hills and the latter at higher altitudes. The multiple correlation analysis showed that only members of the order Odonata have correlation with the abiotic factors at all the sites, while Coleoptera, Diptera, Hemiptera and Ephemeroptera showed only in one or two stations.

In identifying the build up of population by migration and colonization, the light trap experiments helped in determining the critical time. It was shown by the present investigations, that maximum catch invariably occurred in the monsoon season, concurrent with reports elsewhere that rainfall influenced the dispersal rate most. However, in addition to monsoon peak, there was a smaller pre-winter peak. While the major monsoon peak could be attributed to the search of food and habitat for reproduction, the small winter peak is probably for selection of suitable habitats for survival during this adverse period. In any case, the maximum dispersal always seemed to occur just before midnight irrespective of seasons and at both order and familial levels. Hemiptera seemed to be more attracted to light than Coleoptera and possibly this be attributed to the greater flying ability of the members of Corixidae.

The present study took into account, not only the migration to suitable habitats, but also the rate of colonization and hence artificial substrates were utilized for this purpose. It was seen that in both the substrates employed, all the five majo orders were represented; generally the total insects were more i

Littorella than *Rotala rotundifolia*. This probably could be attributed to the greater surface area and the far richer dense cover the latter weed provided. The highest colonization in both *Littorella* and *R. rotundifolia* was seen to be from the order Ephemeroptera at Station 3; at Station 4 ephemerids exceeded in number in *Littorella*, while Odonata was more in *R. rotundifolia*. At the generic and specific levels, it was seen that most insects colonized the artificial substrates primarily to exploit the accumulation of inorganic and organic detritus and the periphyton on these mats. It had been shown that the seasonality of insects in these artificial substrates synchronized very closely to the seasonal studies of natural populations. This evidence unequivocally proves the suitability of such artificial substrates for population measurements. Such substrates are ideal as there is very little disturbance to the system or to the natural vegetation present.

Since one of the objectives of the present study was also to identify the role played by aquatic insects in fish cultural practices, experiments were conducted using the dragonfly nymph (*Orthetrum* sp.), which was a potential predator. It was estimated that the satiation time for a single nymph was about 40 minutes and it took 85 seconds to consume an individual prey. The predator' capacity of these nymphs was quite high and amounted to nearly 16 spawn of *Cyprinus carpio*. The nymphs were found to regain maximum appetite every 24-36 hours after deprivation of food. However, a decline in 'predatory efficiency' was shown after 10 minutes of feeding. It was also shown that the time required for capture and consumption of a single spawn was less in the high prey densities than in low prey densities. This aspect of the present study identified atleast one of these potential predators and offers quantitative data for further investigations.

Finally, in addition to the different aspect of study already presented, an overview of insect population and species composition of the inland waters in the North-Eastern Region of India was attempted at different altitudes. This was undertaken primarily to identify the aquatic insects and their seasonality in both natural and man-made habitats. A very clear pattern of difference emerges in the total number of species being always higher in the altitudes than at the foot hills. However, in terms of abundance, a definite increase in trend is seen as one goes from altitude to lower elevations. There were also differences in species composition, between the high and low altitudes. Further, irrespective of altitudes, some species occur more in summer and other in winter.

It may be concluded that the data presented here on various aspects of the biology of aquatic insects from North-Eastern India, had hardly provided a bird's eye view of the magnitude of the problem. It becomes necessary and imperative to take up detailed investigations on each of these aspects. Such an attempt is already undertaken and the work is in progress on a long term basis.

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